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Woszczak et al.

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(54) **METHOD AND SYSTEM FOR COMPONENT ALIGNMENT IN TURBINE CASING AND RELATED TURBINE CASING**

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F01D 21/00	(2006.01)

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(52) **U.S. Cl.**
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(Continued)

(58) **Field of Classification Search**
CPC F01D 25/24; F01D 25/243; F01D 25/246; F01D 25/28; F01D 21/003; F05D 2230/644; F05D 2260/30; F05D 2240/14
See application file for complete search history.

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(57) **ABSTRACT**

A method and system for aligning a component within a turbine casing, and a related turbine casing, are disclosed. In a top-on position, a location of a reference point and another, vertically spaced reference point on the lower casing are measured. After removing at least the upper casing, the reference points' locations are measured again, and the locations of a reference point on an upper surface of the HJ flange are measured. A prediction offset value is calculated

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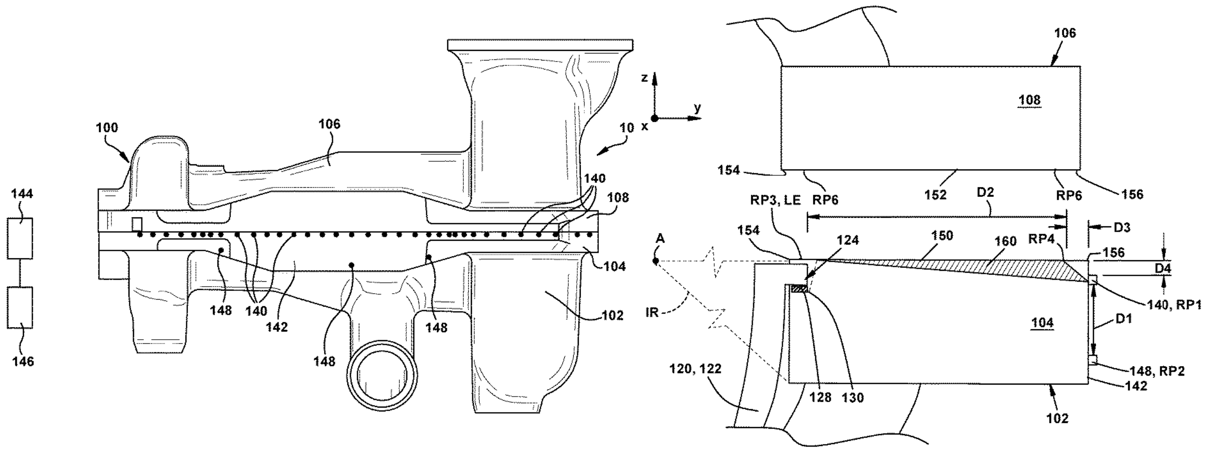

for the component support position in the top-on position based on the locations. The prediction offset value may include a vertical adjustment based, in part, on a translation of a triangular spatial relationship of a number of the reference points and/or a tilt angle, a horizontal adjustment, and a HJ flange surface distortion adjustment. The component support position is adjusted by the prediction offset value to improve alignment.

20 Claims, 17 Drawing Sheets

(51) **Int. Cl.**

F01D 25/02	(2006.01)
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(52) **U.S. Cl.**

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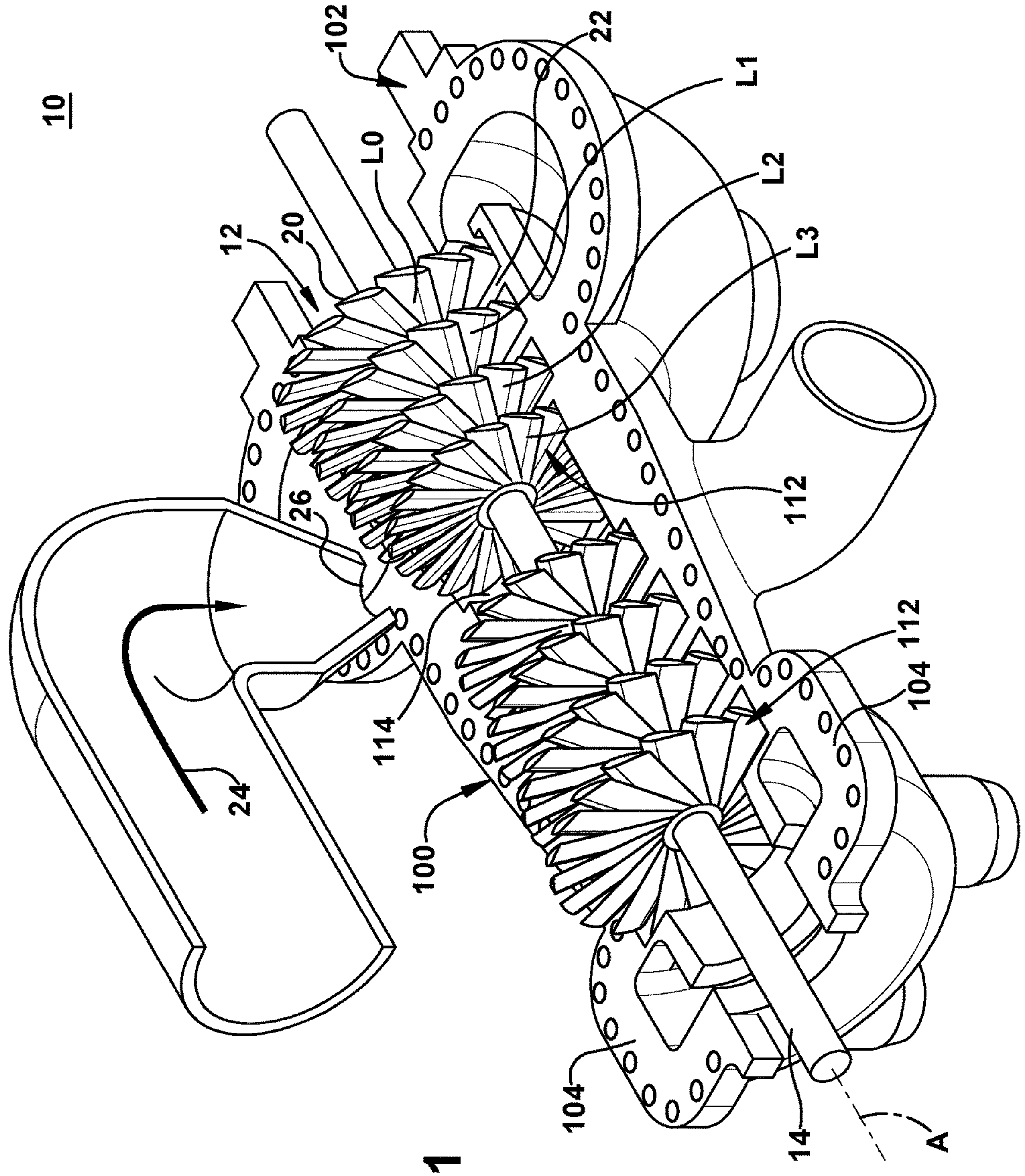

FIG. 1

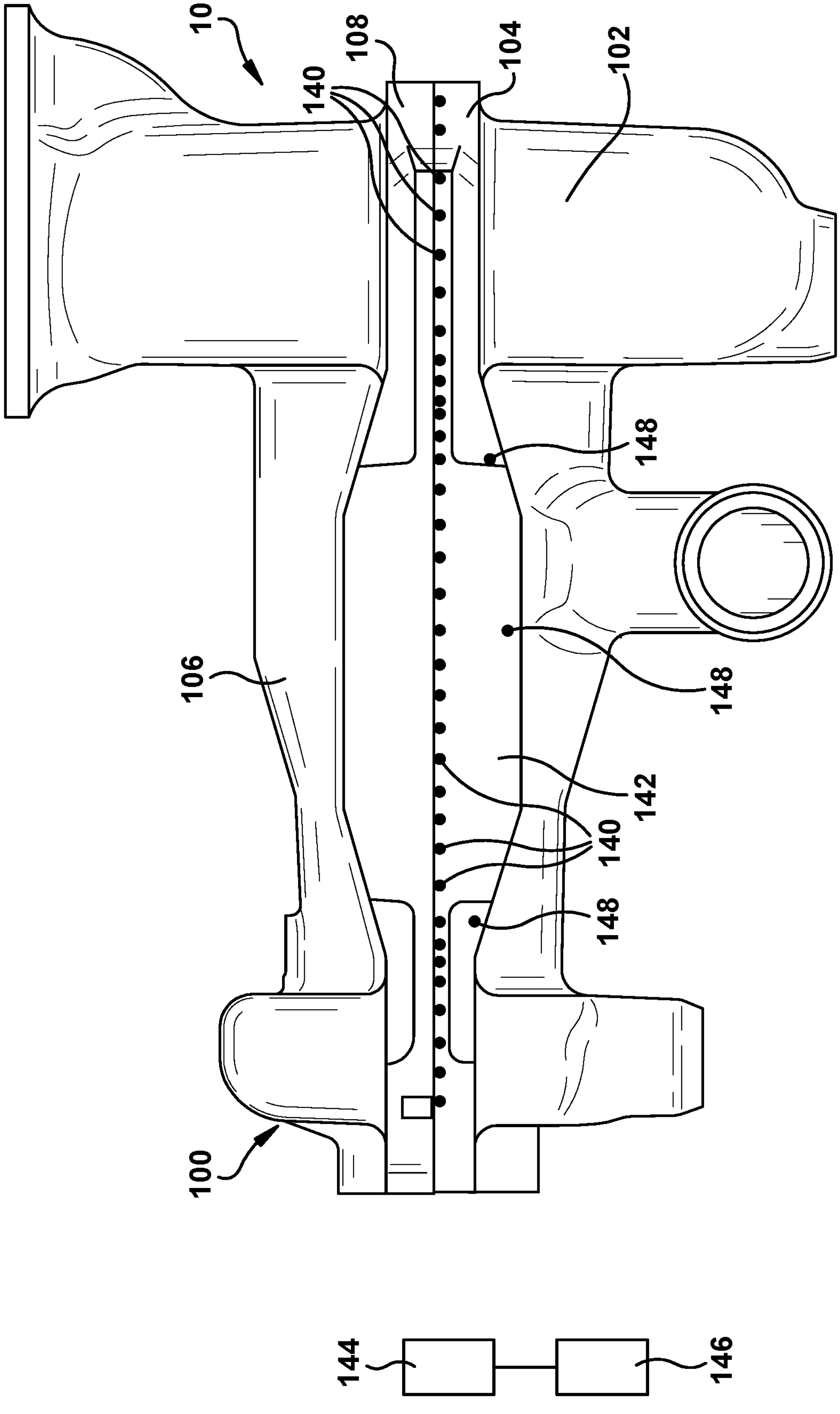

FIG. 2

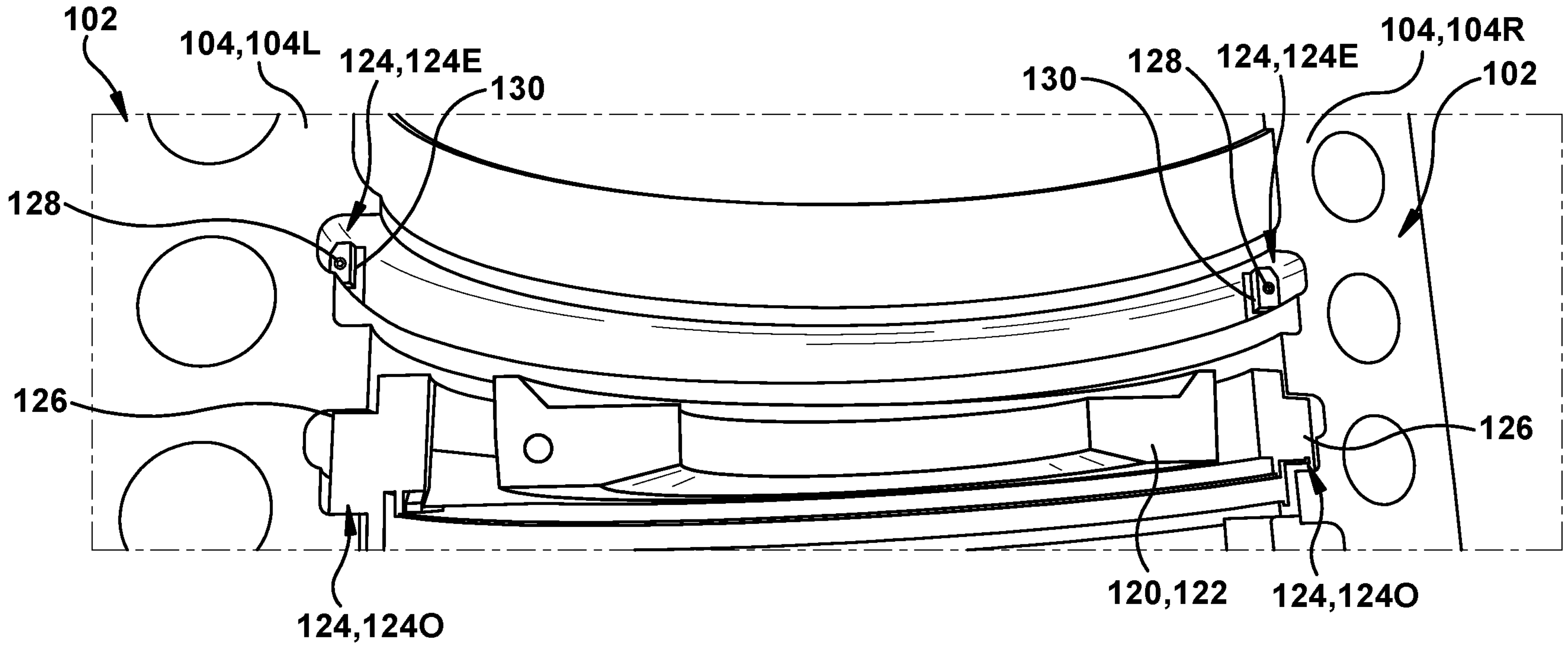
102
104,104L
124,124E
130
128
126
124,124O
130
128
124,124E
104,104R
102
126
120,122
124,124O

FIG. 3

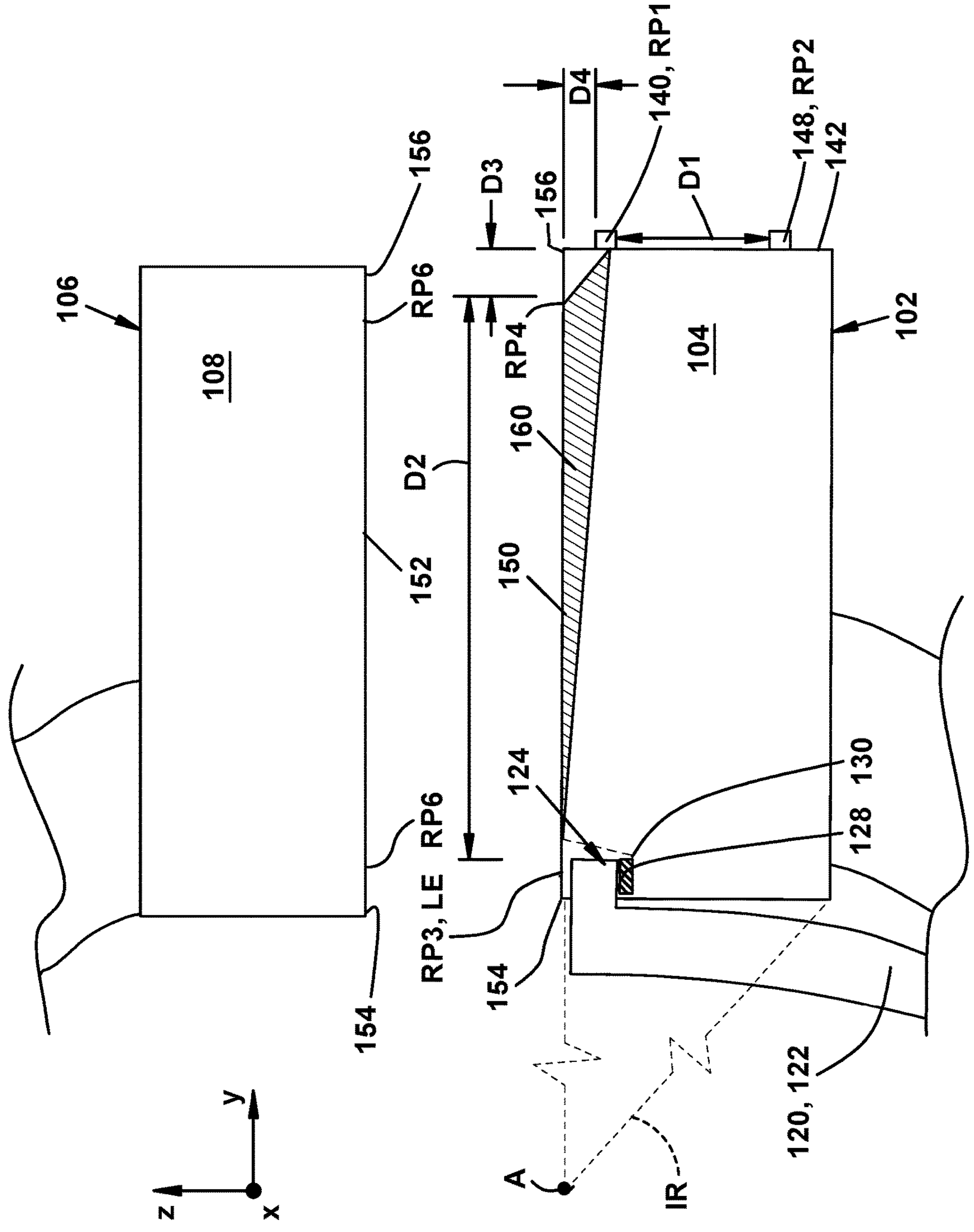
106
108
156
RP6
152
RP6
154
D4
140, RP1
148, RP2
142
D3
156
D1
RP4
104
102
160
D2
150
124
130
128
RP3, LE
154
120, 122
A
IR
y
z
x

FIG. 4

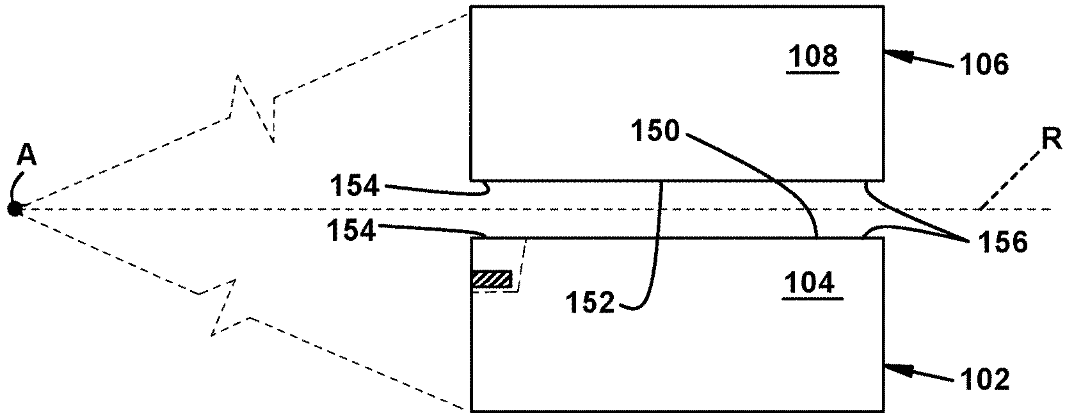

FIG. 5

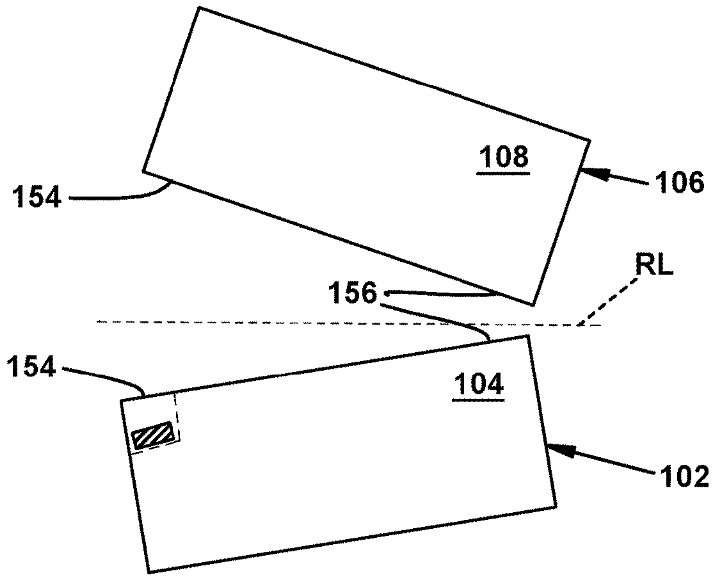

FIG. 6

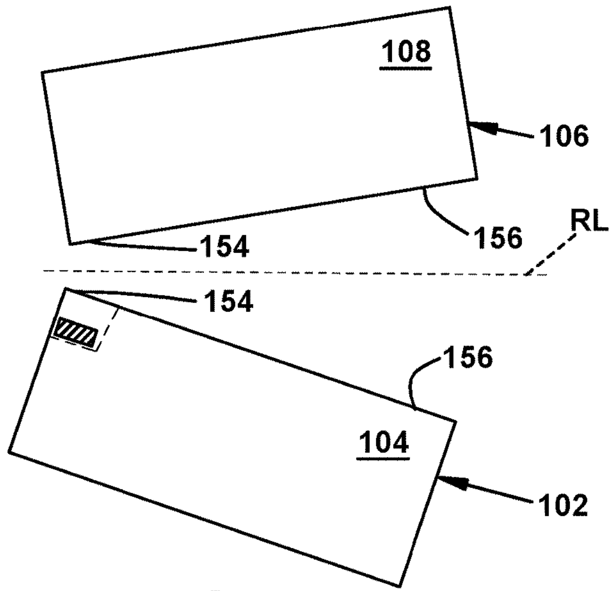

FIG. 7

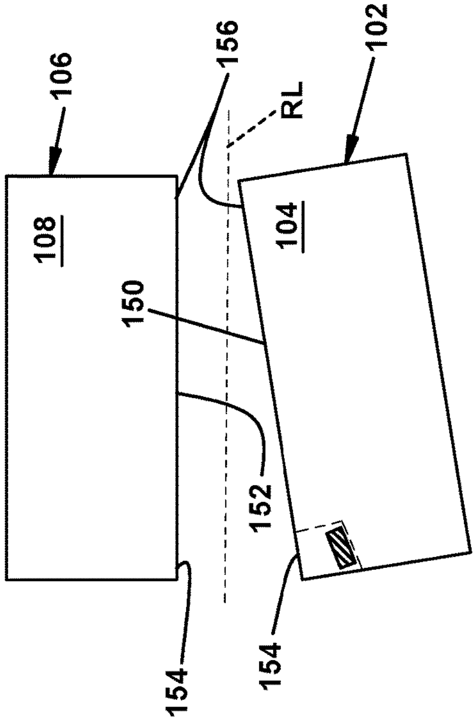

FIG. 8

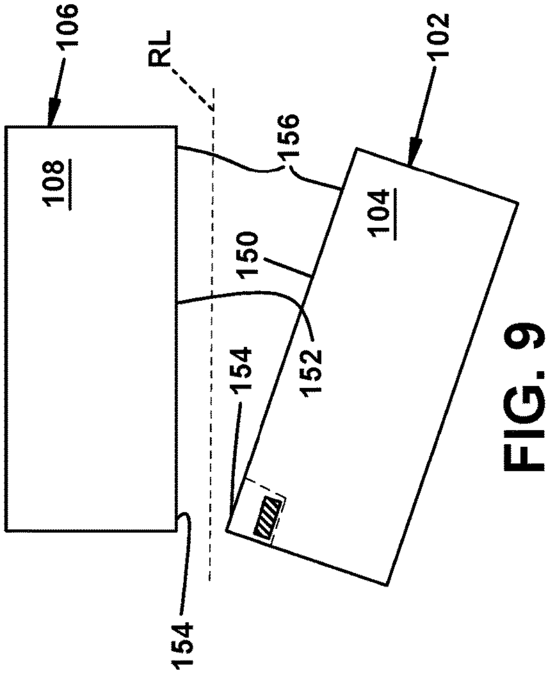

FIG. 9

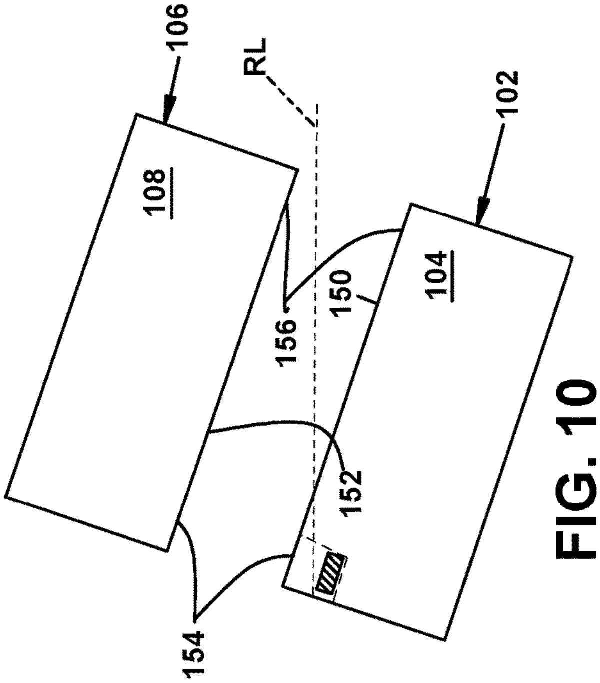

FIG. 10

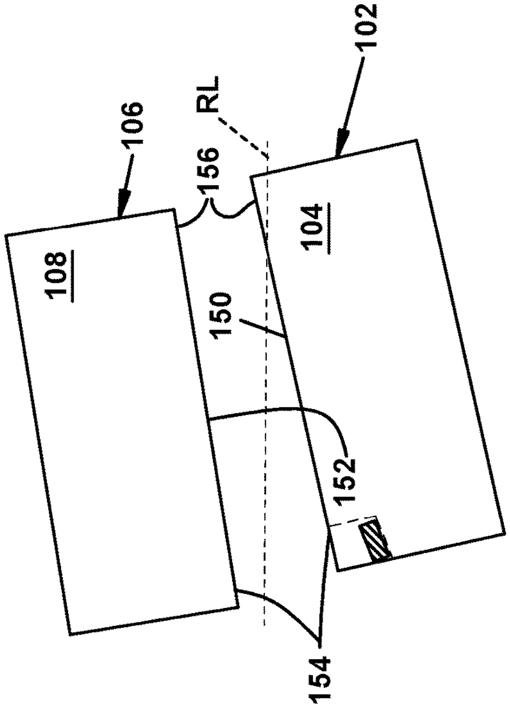

FIG. 11

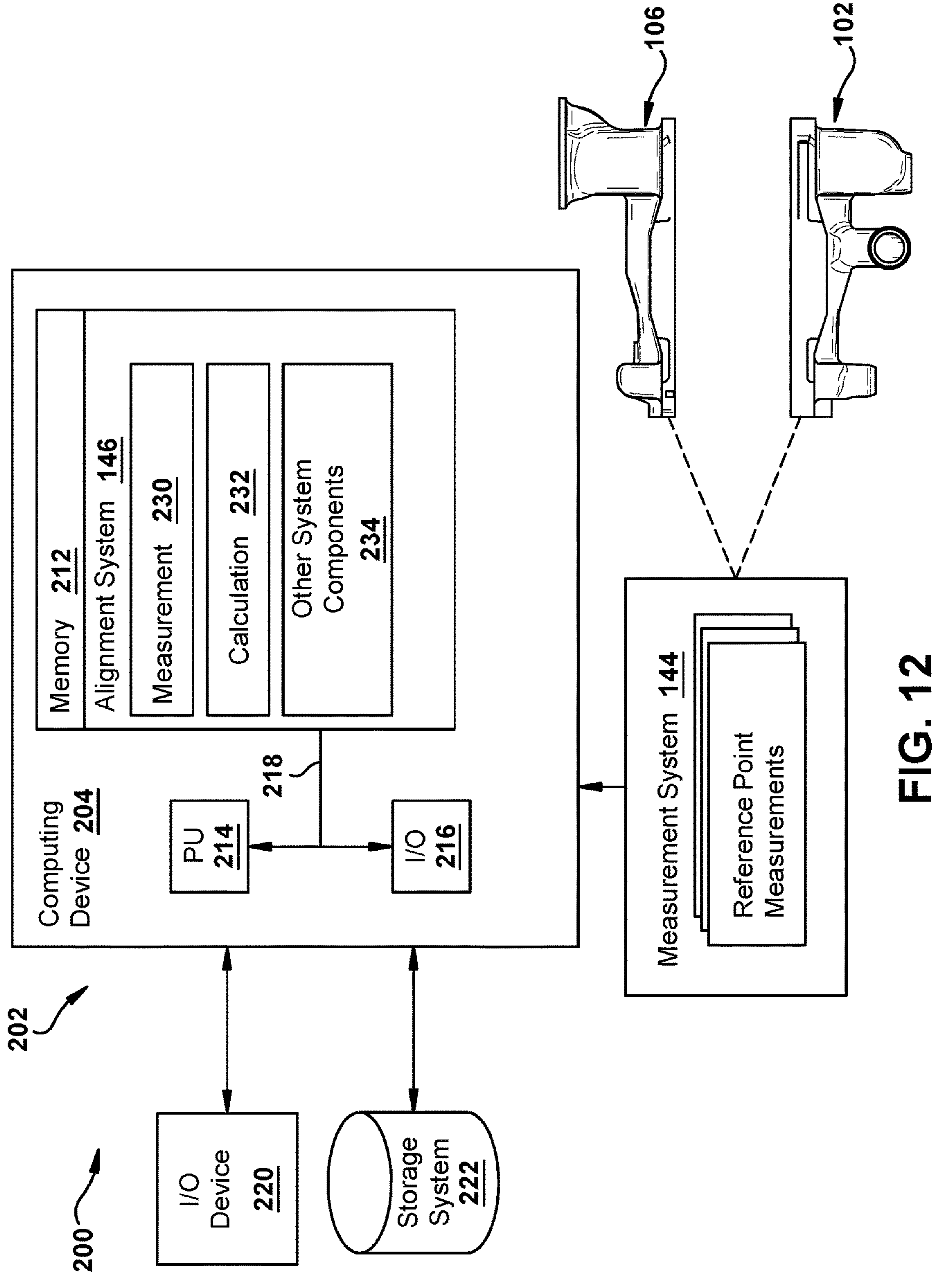
200
202
I/O Device 220
Storage System 222
Computing Device 204
PU 214
I/O 216
218
Memory 212
Alignment System 146
Measurement 230
Calculation 232
Other System Components 234
Measurement System 144
Reference Point Measurements
106
102

FIG. 12

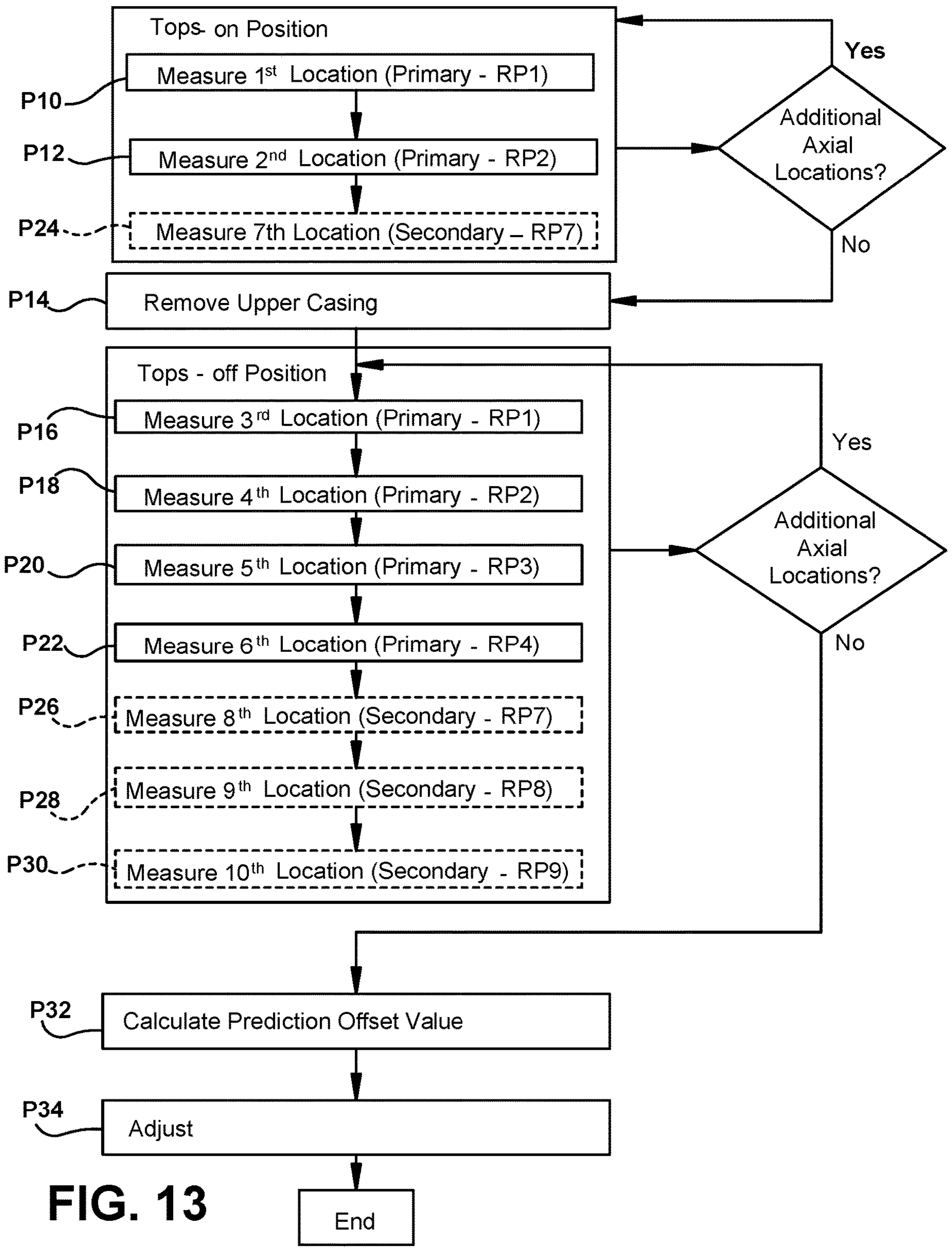
Tops- on Position
Measure 1st Location (Primary - RP1)
P10
Measure 2nd Location (Primary - RP2)
P12
Measure 7th Location (Secondary – RP7)
P24
Yes
Additional Axial Locations?
No
Remove Upper Casing
P14
Tops - off Position
Measure 3rd Location (Primary - RP1)
P16
Measure 4th Location (Primary - RP2)
P18
Measure 5th Location (Primary - RP3)
P20
Measure 6th Location (Primary - RP4)
P22
Measure 8th Location (Secondary - RP7)
P26
Measure 9th Location (Secondary - RP8)
P28
Measure 10th Location (Secondary - RP9)
P30
Yes
Additional Axial Locations?
No
Calculate Prediction Offset Value
P32
Adjust
P34
End

FIG. 13

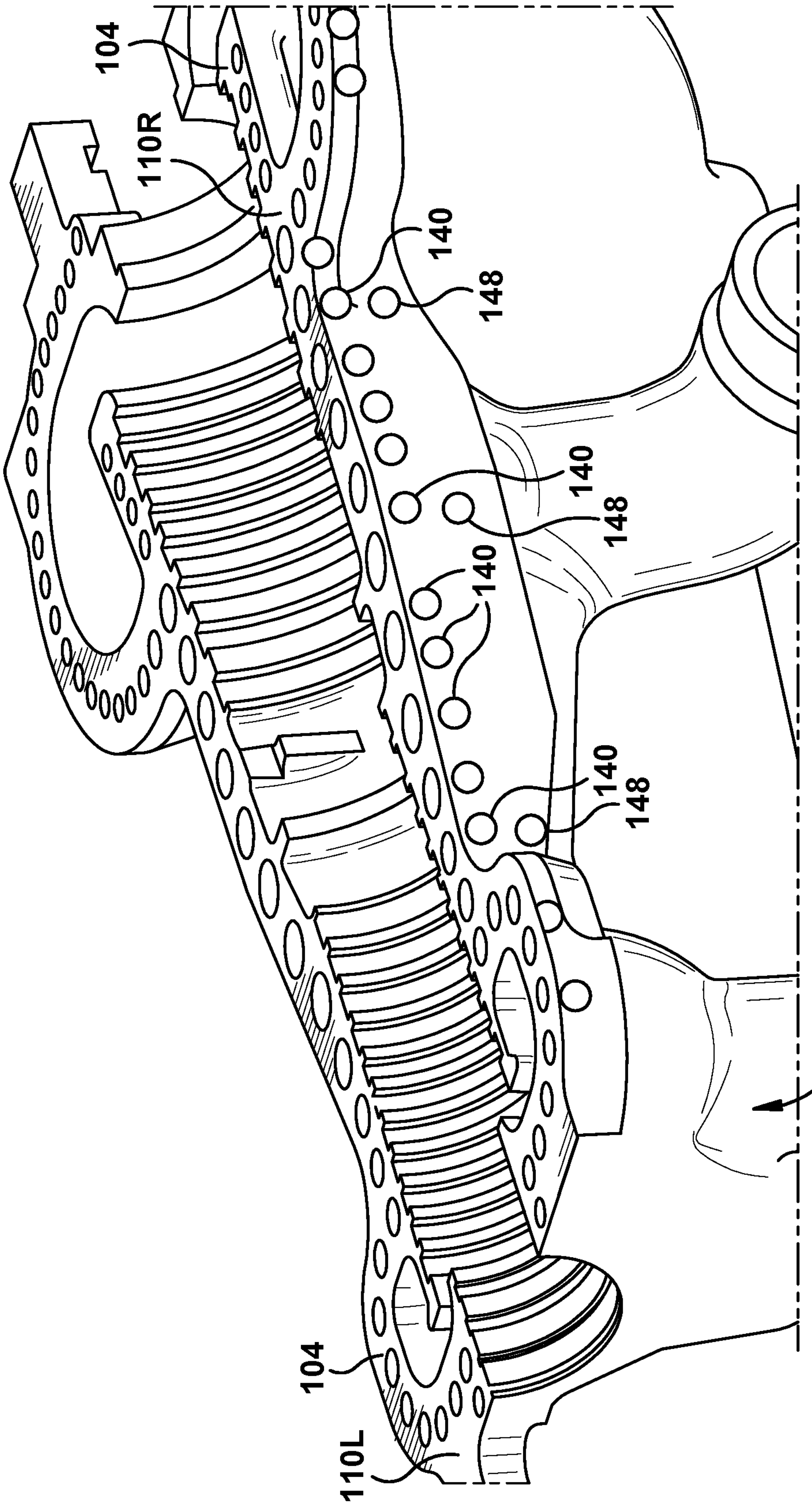

FIG. 14

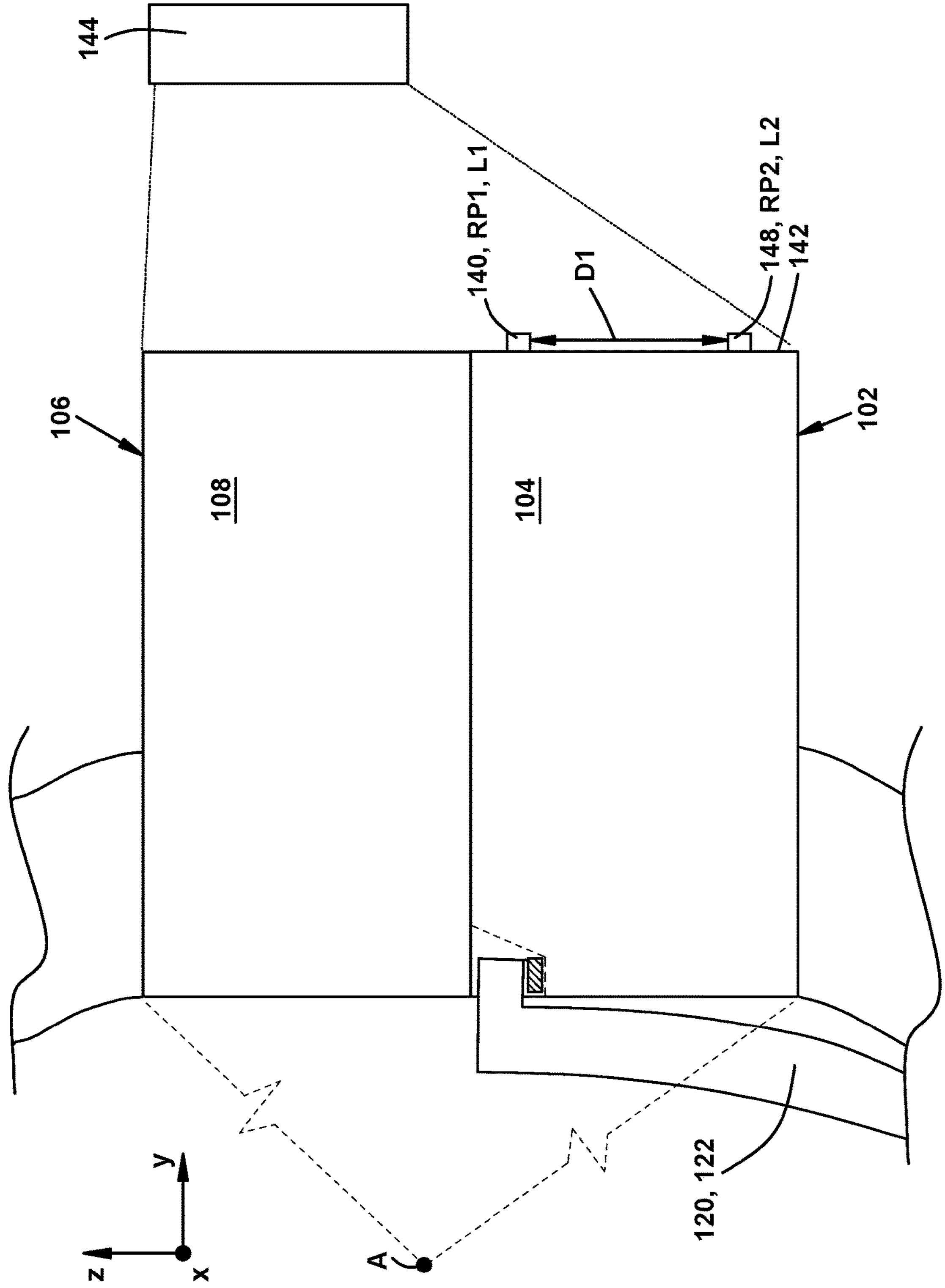

FIG. 15

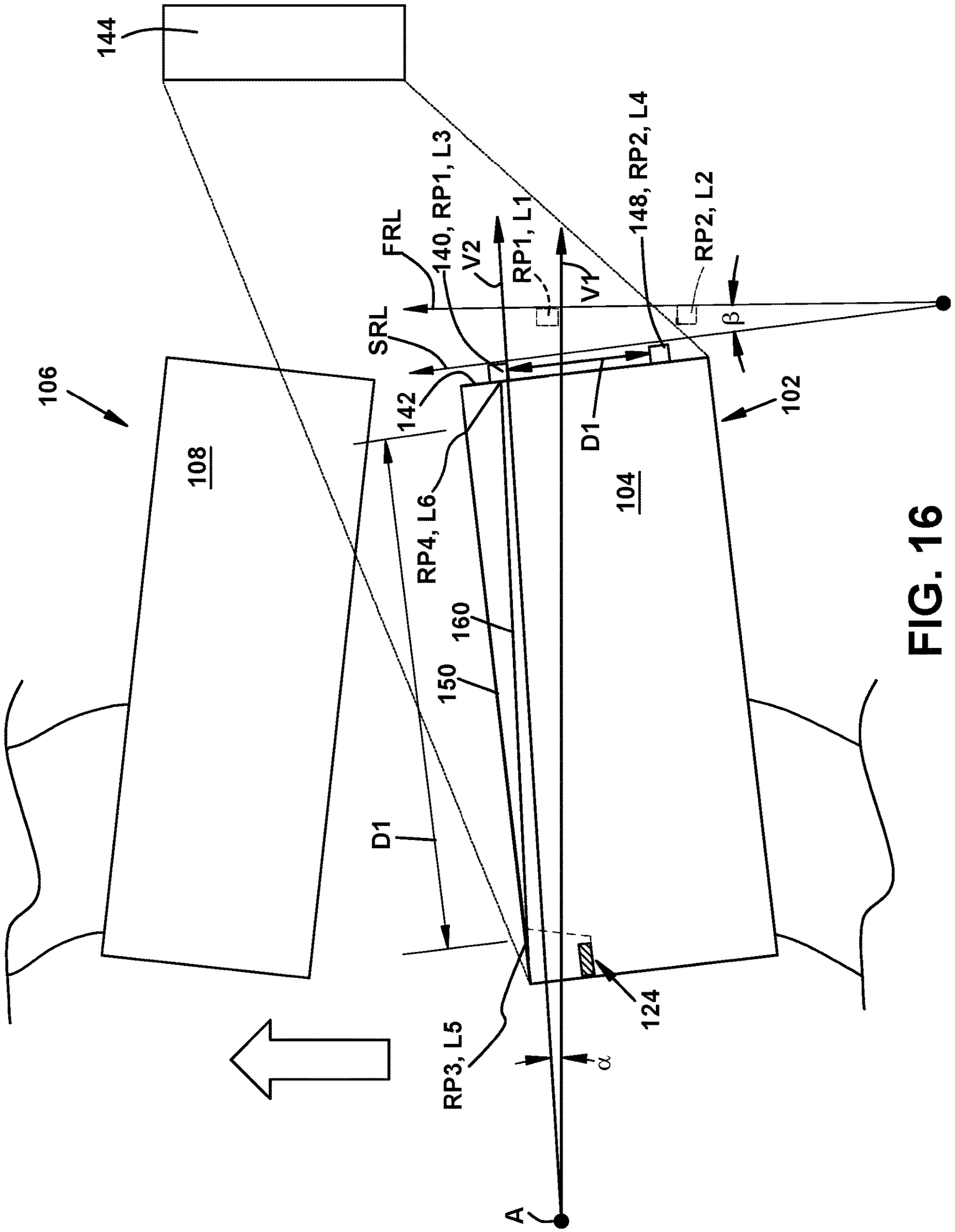
144
106
108
FRL
140, RP1, L3
V2
RP1, L1
V1
148, RP2, L4
RP2, L2
β
SRL
142
102
D1
104
RP4, L6
160
150
D1
124
RP3, L5
α
A

FIG. 16

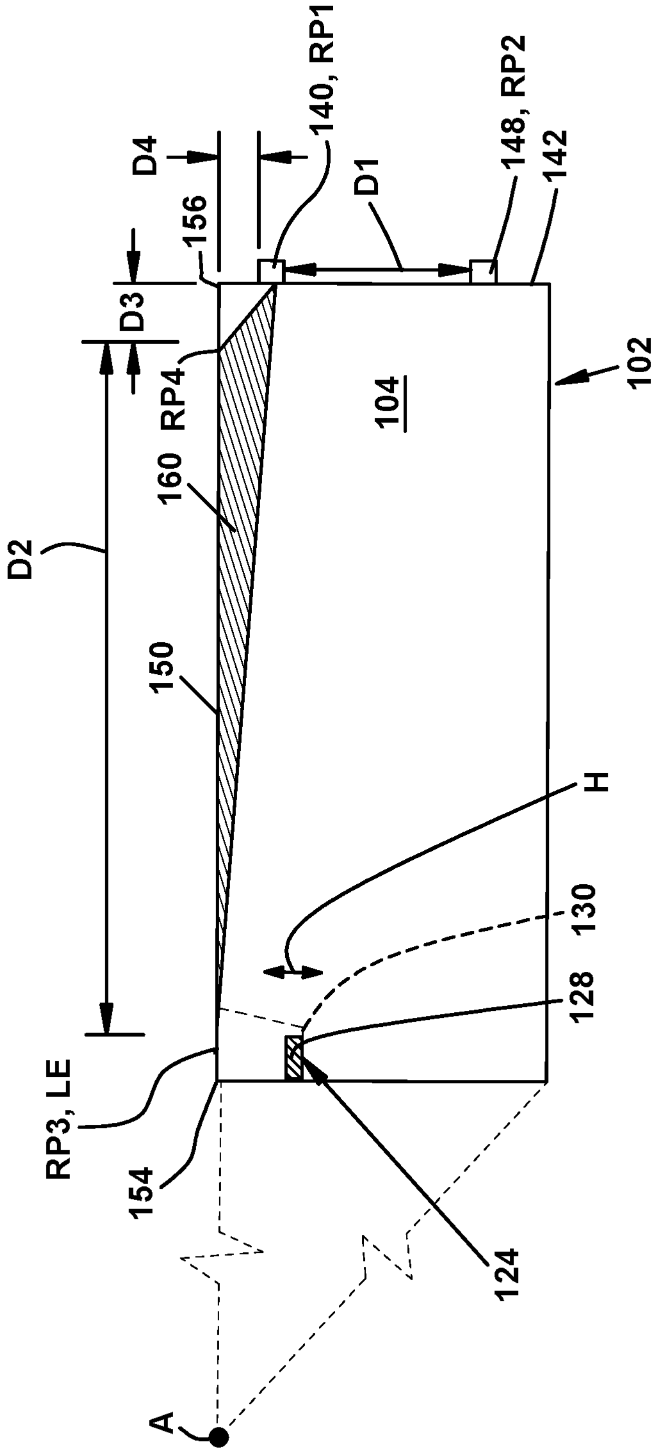
D4
140, RP1
156
D1
148, RP2
142
D3
RP4
104
102
160
D2
150
H
130
128
RP3, LE
154
124
A

FIG. 17

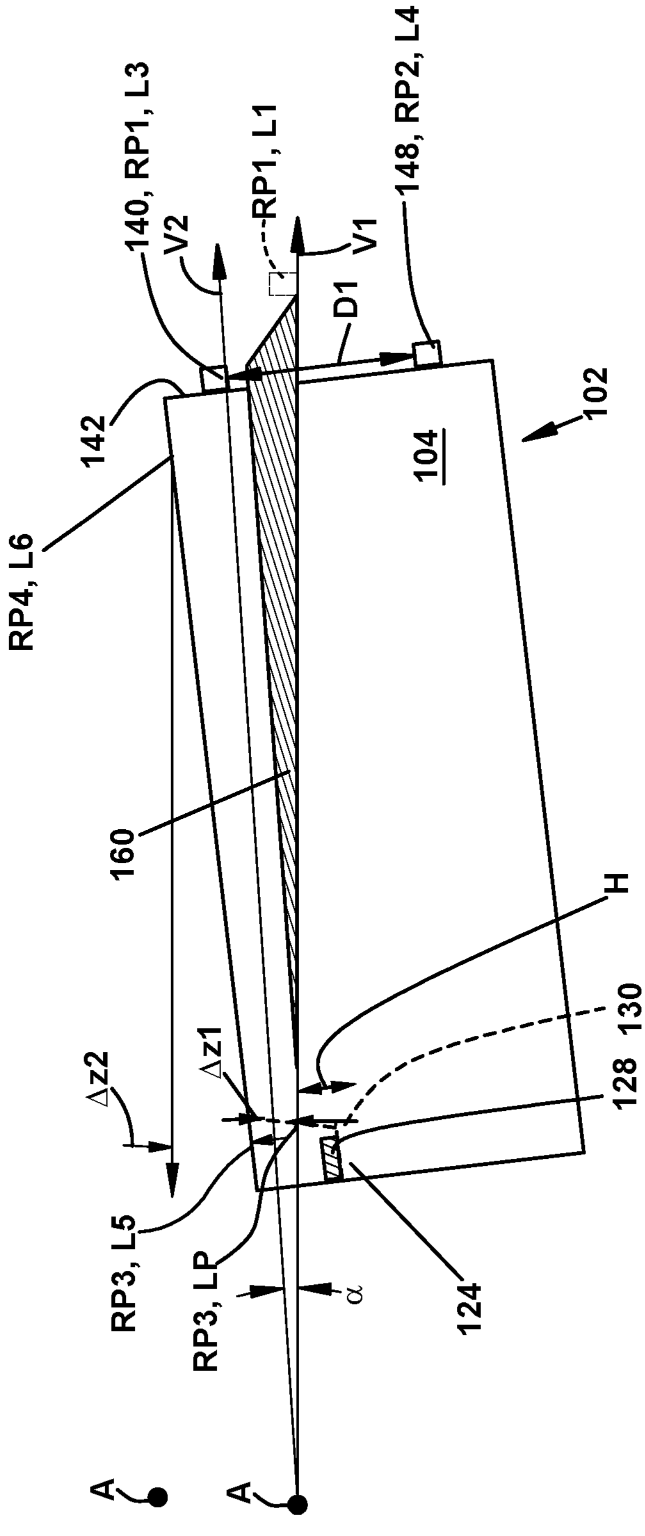
140, RP1, L3
V2
RP1, L1
V1
148, RP2, L4
D1
142
102
104
RP4, L6
160
H
130
128
Δz2
Δz1
RP3, L5
RP3, LP
α
124
A
A

FIG. 18

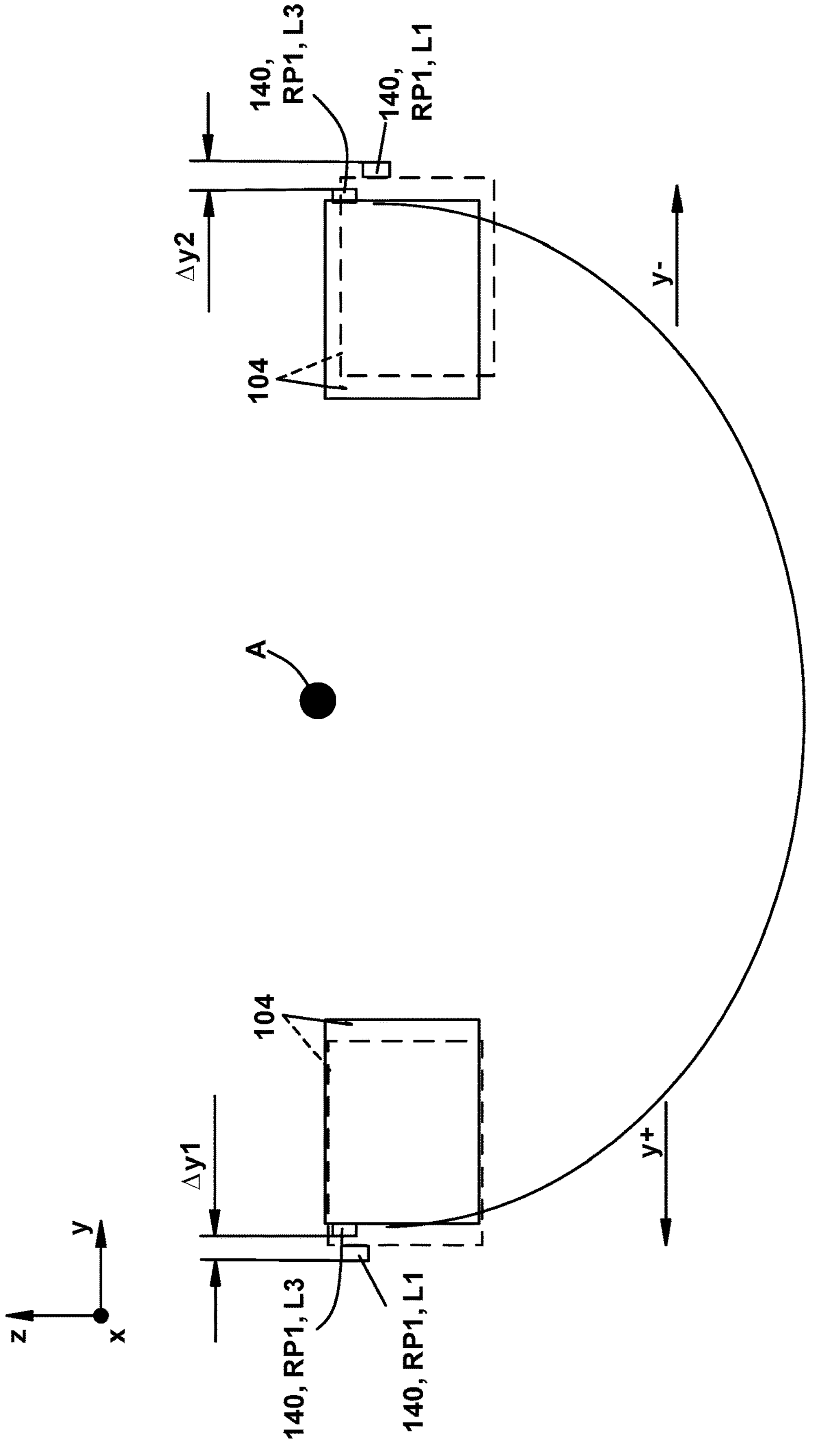
140, RP1, L3
140, RP1, L1
Δy2
104
y-
A
104
Δy1
y+
y
z
x
140, RP1, L3
140, RP1, L1

FIG. 19

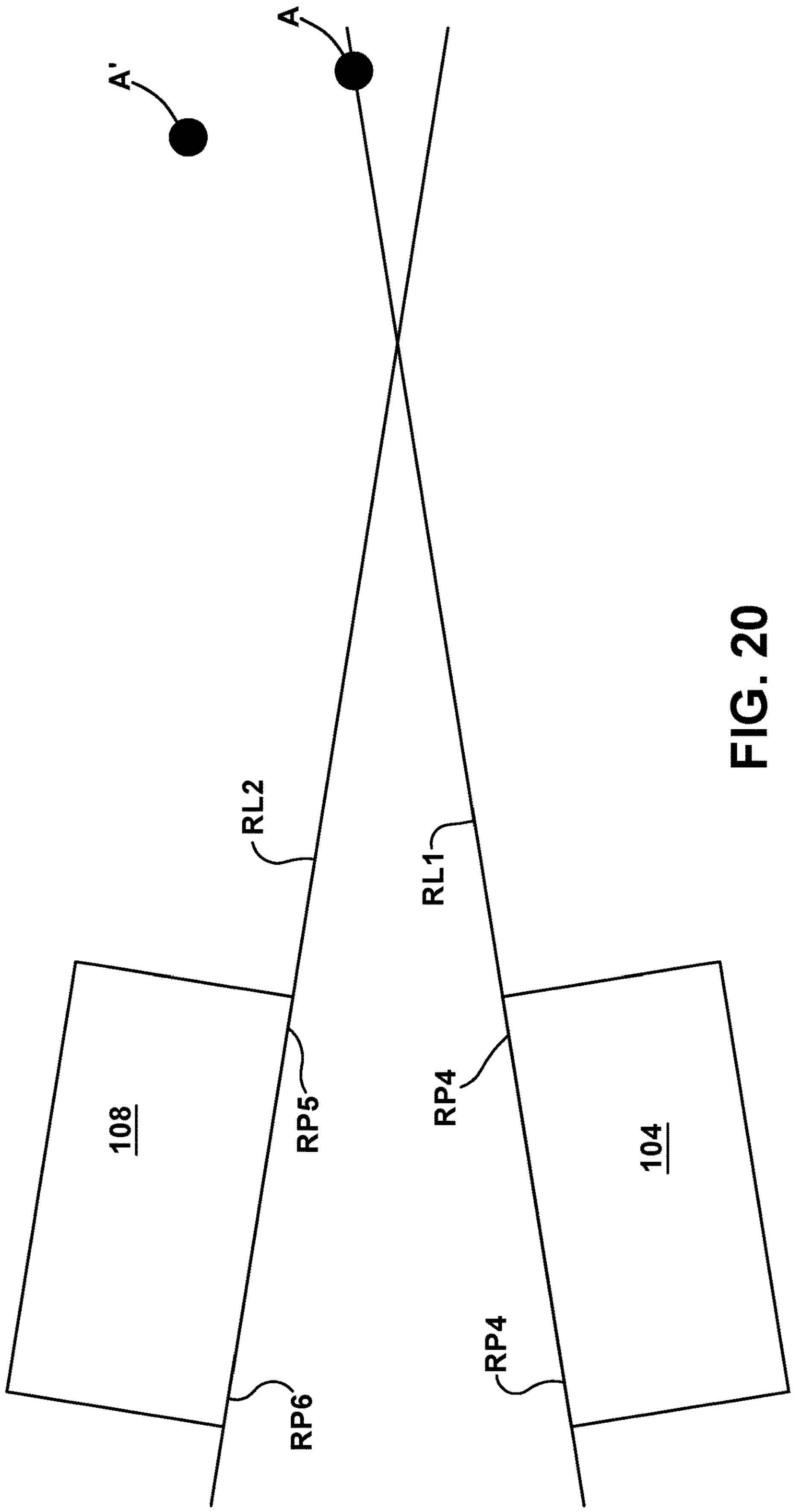

FIG. 20

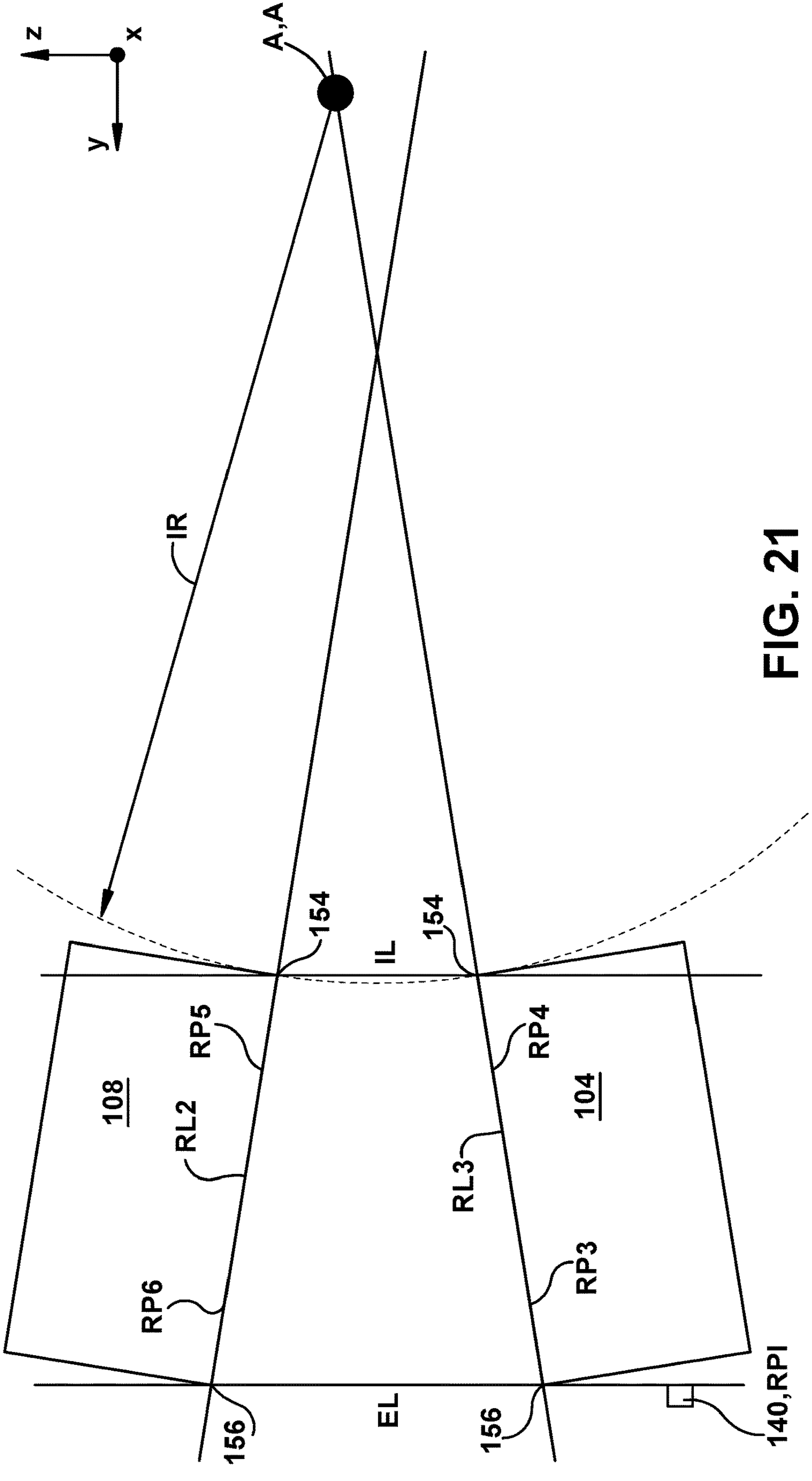
z
x
y
A,A'
IR
154
154
IL
RP5
RP4
108
104
RL2
RL3
RP6
RP3
156
EL
156
140,RPI

FIG. 21

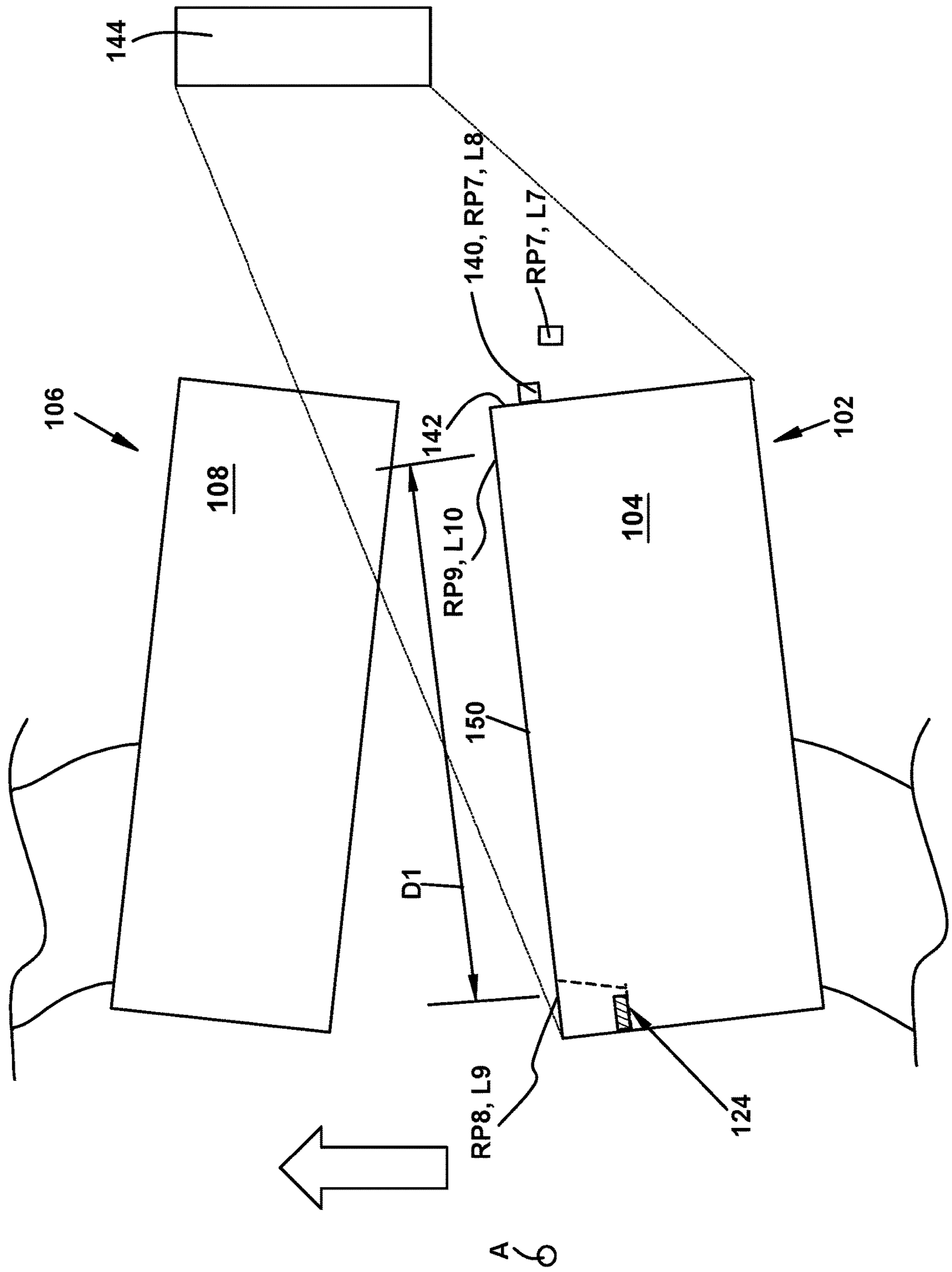
144
140, RP7, L8
RP7, L7
106
108
142
RP9, L10
104
102
150
D1
RP8, L9
124
A

FIG. 22

METHOD AND SYSTEM FOR COMPONENT ALIGNMENT IN TURBINE CASING AND RELATED TURBINE CASING

BACKGROUND OF THE DISCLOSURE

The disclosure relates generally to turbine systems, and more particularly, to a system and method for aligning a component in such turbine systems, and a related turbine casing.

Turbine systems, such as steam turbine (ST) systems or gas turbine (GT) systems, are used in a wide variety of power generating systems. Turbines are typically constructed using one or more removable upper portions (e.g., upper shells or casings) to allow access to components within the turbine. The components within the turbine may include a large number of stationary and rotating components. Rotating components may include one or more wheels, shafts, etc., that rotate during the operation of the turbine. Stationary components may include one or more stationary wheels, diaphragms, support pads, deflectors, casing portions, bearings, etc., that remain stationary during operation of the turbine. Turbines may also include one or more lower portions (e.g., lower shells or casings) that generally serve as a support for the other turbine components and may also assist in sealing the working fluid (e.g., steam or combusted fuel) path to prevent leakage. The upper casing is coupled to the lower casing to create the working fluid path.

Close tolerances among the various components of a turbine directly affect its efficiency. To illustrate, a large steam turbine weighing several tons may have tolerances for internal components measured in millimeters (mm), or in thousandths of an inch (mils). If stationary and rotating components are too close to one another, rubbing between the components may occur during operation. This rubbing makes it difficult to start the turbine after a servicing or overhaul, and generates excessive vibration. The rubbing may also wear the seals between the rotating and stationary components, and after the components have worn, excessive clearance will then exist in the areas in which rubbing occurred. If stationary and rotating components are too far apart from the other, working fluid leakage may occur between the components, reducing the efficiency of the turbine. Accordingly, great care is desirable when servicing or maintaining a turbine to ensure that the various components are aligned and positioned correctly.

During an offline servicing or overhaul of a turbine system, various components of a turbine may be accessed by removing the upper casing or casings, commonly referred to as "tops." With the top-off, stationary and rotating components of the turbine may be inspected, adjusted, cleaned, repaired, replaced, and/or otherwise serviced. One type of inspection may determine the amount of displacement suffered by various components due to turbine operation. For example, certain stationary components might have shifted in alignment. Components that have become misaligned may then be realigned as a part of this inspection. Upon completion of the servicing or overhaul, the upper casing(s) may be replaced, and the turbine returned to operation. Unfortunately, an alignment problem commonly occurs when the top(s) are placed back on the lower casing. The upper casing(s) may weigh one ton or more, and the placement of these upper casing(s) onto the turbine may cause an additional amount of displacement or distortion among the previously-aligned components. Such displacement may generally be referred to herein as 'top-on displacement.' For example, a lower casing might spring up, or bow or sag between support points when in the top-off condition, and one or more stationary components connected to the lower casing, for example, the diaphragm portions, may shift. If the components are aligned with the top-off, they may shift when the tops are placed back on, and may actually shift out of alignment.

To address this problem, it is conventional practice to conduct a top-on/top-off alignment procedure. In this procedure, the upper casing(s) is/are first removed and the various components are removed and serviced, as needed. After these components are removed, the upper casing(s) are replaced, and the various component support positions within the couple casings are measured for position both vertically and transversely with respect to the centerline of the unit. Then, the upper casing(s) are once again removed, and a top-off line is measured. The top-off line measures the transverse and vertical positions of the internal components with the upper casing(s) and/or components removed. Then, these measurements are compared to determine an ideal position for the internal components when in the top-off condition. Then, with the upper casing(s) removed, the component support positions are adjusted to account for the top-on displacement. For example, a seat upon which a diaphragm portion sits may be adjusted to ensure the center of the diaphragm is aligned with the rotor axis. When the tops are placed back on, the components are then expected to shift into alignment. For example, a set of top-on and top-off measurements might show that a particular component shifts upwards 0.25 millimeters (mm) when the tops are placed on. This component may be aligned, in the top-off condition, to be 0.25 mm low to account for this rise.

The top-on/top-off procedure described above helps to ensure that various turbine components are in optimal alignment at the completion of the servicing. However, the top-on/top-off procedure is extremely time consuming. Many hours are required to perform the various measurements, as well as removing and replacing the upper casing(s) twice, resulting in higher costs for personnel time and a greater amount of lost revenue due to the turbine being offline. The process can be further complicated because, when assembled without the rotor and/or other internal components, the full turbine casing is not fully representative of the top-on conditions because some of the internal components, e.g., the diaphragms and carriers, associated with the upper casing and the rotor are not present. The current process can therefore be inaccurate. Consequently, the alignment process may need to be repeated, which adds to costs. One approach to address these issues measures right and left component supports and/or inner shell displacements in a top-off situation, and calculates predicted vertical and/or transverse offset values that are percentages of the measured displacements for adjustment of components. While this approach eliminates the repetitive assembly, it does not consider the complete top-on situation, and can be inaccurate.

BRIEF DESCRIPTION OF THE DISCLOSURE

A first aspect of the disclosure provides a method of aligning a component within a turbine casing, the turbine casing including an upper casing and a lower casing configured to collectively surround a rotor, the rotor having a rotor axis, the method comprising: for at least one primary axial location along the rotor axis and at one or both sides of the turbine casing at each primary axial location: with the upper casing coupled to the lower casing in a top-on position, measuring: a first location of a first reference point at a first optical target coupled to an outer surface of a horizontal joint (HJ) flange of the lower casing, and a second location of a second reference point at a second optical target coupled to the outer surface of the HJ flange of the lower casing and vertically spaced from the first optical target; with at least the upper casing removed from the lower casing in a top-off position, measuring: a third location of the first reference point at the first optical target, a fourth location of the second reference point at the second optical target, a fifth location of a third reference point on an upper surface of the horizontal joint (HJ) flange of the lower casing, the third reference point having a known spatial relation to a component support position of the component in the lower casing at the respective primary axial location, and a sixth location of a fourth reference point on the upper surface of the HJ flange of the lower casing, the fourth reference point spaced from the third reference point on the upper surface of the HJ flange of the lower casing; calculating a prediction offset value for the component support position in the top-on position based on at least the first, second, third, fourth, fifth and sixth locations and an inner radius of the lower casing; and adjusting the component support position in the turbine casing by the prediction offset value, wherein an alignment of the component positioned at the component support position is improved relative to the rotor axis upon replacing the upper casing to the top-on position.

A second aspect of the disclosure provides a system for aligning a component within a turbine casing, the turbine casing including an upper casing and a lower casing configured to collectively surround a rotor, the rotor having a rotor axis, the system comprising: a measurement module configured to: for at least one primary axial location along the rotor axis and at one or both sides of the turbine casing at each primary axial location: with the upper casing coupled to the lower casing in a top-on position, receive a measurement of: a first location of a first reference point at a first optical target coupled to an outer surface of a horizontal joint (HJ) flange of the lower casing, and a second location of a second reference point at a second optical target coupled the outer surface of the HJ flange of the lower casing and vertically spaced from the first optical target; with at least the upper casing removed from the lower casing in a top-off position, receive a measurement of: a third location of the first reference point at the first optical target, a fourth location of the second reference point at the second optical target, a fifth location of a third reference point on an upper surface of the horizontal joint (HJ) flange of the lower casing, the third reference point having a known spatial relation to a component support position of the component in the lower casing at the respective primary axial location, and a sixth location of a fourth reference point on the upper surface of the HJ flange of the lower casing, the fourth reference point spaced from the third reference point on the upper surface of the HJ flange of the lower casing; and a calculation module configured to: calculate a prediction offset value for the component support position in the top-on position based on at least the first, second, third, fourth, fifth and sixth locations and an inner radius of the lower casing, and indicate an adjustment for the component support position in the turbine casing at the at least one primary axial location based on the prediction offset value.

A third aspect includes a turbine casing, comprising: an upper casing having an upper horizontal joint (HJ) flange; a lower casing having a lower horizontal joint (HJ) flange, wherein the upper casing and the lower casing are configured to collectively surround a turbine rotor and a plurality of turbine blades coupled to the turbine rotor; and a plurality of first optical targets, each first optical target positioned at one of a plurality axial locations extending along a radially facing outer surface of the lower HJ flange of the lower casing.

The illustrative aspects of the present disclosure are designed to solve the problems herein described and/or other problems not discussed.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features of this disclosure will be more readily understood from the following detailed description of the various aspects of the disclosure taken in conjunction with the accompanying drawings that depict various embodiments of the disclosure, in which:

FIG. **1** shows a perspective partial cut-away illustration of a steam turbine with an upper casing removed.

FIG. **2** shows a side view of a turbine casing according to embodiments of the disclosure.

FIG. **3** shows a top down view of a component support position in a lower casing in a top-off position, according to embodiments of the disclosure.

FIG. **4** shows a partial cross-sectional view of a component in a component support position in a lower casing in a top-off position, according to embodiments of the disclosure.

FIG. **5** shows a schematic cross-sectional view of a first scenario of horizontal joint (HJ) flanges of a turbine casing in a top-off position, according to embodiments of the disclosure.

FIG. **6** shows a schematic cross-sectional view of a second scenario of HJ flanges of a turbine casing in a top-off position, according to embodiments of the disclosure.

FIG. **7** shows a schematic cross-sectional view of a third scenario of HJ flanges of a turbine casing in a top-off position, according to embodiments of the disclosure.

FIG. **8** shows a schematic cross-sectional view of a fourth scenario of HJ flanges of a turbine casing in a top-off position, according to embodiments of the disclosure.

FIG. **9** shows a schematic cross-sectional view of a fifth scenario of HJ flanges of a turbine casing in a top-off position, according to embodiments of the disclosure.

FIG. **10** shows a schematic cross-sectional view of a sixth scenario of HJ flanges of a turbine casing in a top-off position, according to embodiments of the disclosure.

FIG. **11** shows a schematic cross-sectional view of a seventh scenario of HJ flanges of a turbine casing in the top-off position, according to embodiments of the disclosure.

FIG. **12** shows a block diagram of an environment for an alignment system, according to embodiments of the disclosure.

FIG. **13** shows a flow diagram of a method according to embodiments of the disclosure.

FIG. **14** shows a perspective view of a lower casing in a top-off position, according to embodiments of the disclosure.

FIG. **15** shows a schematic cross-sectional view of HJ flanges of a turbine casing in a top-on position at a primary axial location, according to embodiments of the disclosure.

FIG. **16** shows a schematic cross-sectional view of the HJ flanges of a turbine casing in a top-off position at a primary axial location, according to embodiments of the disclosure.

FIG. **17** shows an enlarged, schematic cross-sectional view of a lower HJ flange of a turbine casing at a primary axial location with potential adjustments illustrated, according to embodiments of the disclosure.

FIG. **18** shows a schematic cross-sectional view of a lower HJ flange of a turbine casing in a top-off position at a primary axial location and with a triangular spatial relationship translated thereon, according to embodiments of the disclosure.

FIG. **19** shows a schematic cross-sectional view of a HJ flange for calculating a horizontal adjustment, according to embodiments of the disclosure.

FIG. **20** shows a schematic cross-sectional view of a HJ flanges superimposed with surface reference lines to identify a surface distortion, according to embodiments of the disclosure.

FIG. **21** shows a schematic cross-sectional view of establishing an angular relationship between the reference lines of FIG. **20**, according to embodiments of the disclosure.

FIG. **22** shows a schematic cross-sectional view of HJ flanges of a turbine casing at a secondary axial location in a top-off position, according to embodiments of the disclosure.

It is noted that the drawings of the disclosure are not to scale. The drawings are intended to depict only typical aspects of the disclosure, and therefore should not be considered as limiting the scope of the disclosure. In the drawings, like numbering represents like elements between the drawings.

DETAILED DESCRIPTION OF THE DISCLOSURE

As an initial matter, in order to clearly describe the current disclosure it will become necessary to select certain terminology when referring to and describing relevant machine components within a turbine system. When doing this, if possible, common industry terminology will be used and employed in a manner consistent with its accepted meaning. Unless otherwise stated, such terminology should be given a broad interpretation consistent with the context of the present application and the scope of the appended claims. Those of ordinary skill in the art will appreciate that often a particular component may be referred to using several different or overlapping terms. What may be described herein as being a single part may include and be referenced in another context as consisting of multiple components. Alternatively, what may be described herein as including multiple components may be referred to elsewhere as a single part.

In addition, several descriptive terms may be used regularly herein, and it should prove helpful to define these terms at the onset of this section. These terms and their definitions, unless stated otherwise, are as follows. As used herein, “downstream” and “upstream” are terms that indicate a direction relative to the flow of a fluid, such as the working fluid through the turbine system or, for example, the flow of air through the combustor or coolant through one of the turbine system’s component systems. The term “downstream” corresponds to the direction of flow of the fluid, and the term “upstream” refers to the direction opposite to the flow. The terms “forward” and “aft,” without any further specificity, refer to directions, with “forward” referring to the front or compressor end of the engine, and “aft” referring to the rearward or turbine end of the engine. It is often required to describe parts that are at differing radial positions with regard to a center axis. The term “radial” refers to movement or position perpendicular to an axis. In cases such as this, if a first component resides closer to the axis than a second component, it will be stated herein that the first component is “radially inward” or “inboard” of the second component. If, on the other hand, the first component resides further from the axis than the second component, it may be stated herein that the first component is “radially outward” or “outboard” of the second component. The term “axial” refers to movement or position parallel to an axis, e.g., the turbine rotor axis. Finally, the term “circumferential” refers to movement or position around an axis. It will be appreciated that such terms may be applied in relation to the center axis of the turbine.

In addition, several descriptive terms may be used regularly herein, as described below. The terms “first”, “second”, and “third” may be used interchangeably to distinguish one component from another and are not intended to signify location or importance of the individual components.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the disclosure. As used herein, the singular forms “a,” “an,” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises” and/or “comprising,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. “Optional” or “optionally” means that the subsequently described event or circumstance may or may not occur, and that the description includes instances where the event occurs and instances where it does not.

Where an element or layer is referred to as being “on,” “engaged to,” “disengaged from,” “connected to,” or “coupled to” another element or layer, it may be directly on, engaged, connected or coupled to the other element or layer, or intervening elements or layers may be present. In contrast, when an element is referred to as being “directly on,” “directly engaged to,” “directly connected to,” or “directly coupled to” another element or layer, there may be no intervening elements or layers present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., “between” versus “directly between,” “adjacent” versus “directly adjacent,” etc.). As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

As indicated above, the disclosure provides a method and system for aligning a component within a turbine casing, and a related turbine casing. In a top-on position, a location of the optical target and another, vertically spaced optical target on a horizontal joint (HJ) flange of the lower casing are measured at one or more primary axial locations. After removing at least the upper casing, the optical targets’ locations are measured again, and the locations of a pair of reference points on an upper surface of the HJ flange, are measured. A prediction offset value is calculated for the component support position in the top-on position based on at least the measured locations. The prediction offset value may include a number of calculated adjustments. In one example, a tilt angle of the lower casing and a rotation angle of the lower casing can be calculated, and a vertical adjustment made based on both. In another example, a horizontal adjustment can be calculated based on the horizontal shift of the lower casing from the top-on to the top-off position. In another example, an HJ flange surface distortion can be identified by superimposing reference lines of the HJ flange surfaces and identifying any gaps at an inner or outer location of mating of the surfaces with the prediction offset value including a correction based on the surface distortion. Similar prediction offset values can be calculated for other secondary axial locations that include only one optical target. In any event, the component support position at a variety of axial locations may be adjusted by the prediction offset value to improve alignment at each axial location. The method and system reduce the lifting required and can address practically all of the alignment issues.

A. Turbine System and Turbine Casing

Referring to the drawings, FIG. **1** shows a perspective partial cut-away illustration of an illustrative turbine system in the form of a steam turbine (ST) system **10**. ST system **10** includes a rotor **12** that includes a turbine rotor **14** and a plurality of axially spaced rotor wheels **18**. Turbine rotor **14** has a rotor axis A. A plurality of rotating turbine blades **20** are mechanically coupled to each rotor wheel **18**. More specifically, turbine blades **20** are arranged in rows that extend circumferentially around each rotor wheel **18**. A plurality of stationary vanes **22** extends circumferentially around turbine rotor **14**, and the vanes are axially positioned between adjacent rows of turbine blades **20**. Stationary vanes **22** cooperate with turbine blades **20** to form a stage and to define a portion of a steam flow path through ST system **10**. In one embodiment of the present disclosure, as shown in FIG. **1**, ST system **10** comprises five stages. The five stages are referred to as L**0**, L**1**, L**2**, L**3** and L**4**. Stage L**4** is the first stage and is the smallest (in a radial direction) of the five stages. Stage L**3** is the second stage and is the next stage in an axial direction. Stage L**2** is the third stage and is shown in the middle of the five stages. Stage L**1** is the fourth and next-to-last stage. Stage L**0** is the last stage and is the largest (in a radial direction). It is to be understood that five stages are shown as one example only, and each turbine system may have more or less than five stages. Also, as will be described herein, the teachings of the disclosure do not require a multiple stage turbine.

In operation, a working fluid, here steam, **24** enters an inlet **26** of ST system **10** and is channeled through stationary vanes **22**. Vanes **22** direct steam **24** downstream against turbine blades **20**. Steam **24** passes through the remaining stages imparting a force on turbine blades **20** causing turbine rotor **14** to rotate. At least one end of ST system **10** may extend axially away from rotor **12** and may be attached to a load or machinery (not shown) such as, but not limited to, a generator, and/or another turbine.

While embodiments of the disclosure will be described relative to ST system **10**, it will be readily understood that the teachings of the disclosure are applicable to a variety of turbine systems and/or other industrial machines having heavy mating casings or parts that require component alignment.

As shown in a side perspective view of FIG. **2**, ST system **10** may include a turbine casing **100** including a lower casing **102** having a lower horizontal joint (HJ) flange **104**, and an upper casing **106** having an upper horizontal joint (HJ) flange **108**. (Note, FIG. **2** shows ST system **10** with any insulation and much of its piping removed.) Lower and upper casings **102**, **106** may each represent any degree of a 360° casing that collectively surround turbine rotor **14**. That is, upper casing(s) **106** and lower casing(s) **102** are collectively configured to surround turbine rotor **14** (FIG. **1**) and turbine blades **20** (FIG. **1**) coupled to the turbine rotor. The disclosure will be described relative to a single upper casing **106** and single lower casing **102**, it will be appreciated by those with skill in the art that the teachings are applicable to turbine systems having numerous upper and/or lower casings. In any event, upper casing **106** and lower casing **102** are configured to collectively surround turbine rotor **14** and turbine blades **20** coupled to turbine rotor **14**. Upper casing **106** and lower casing **102** can be attached, for example, by fasteners, at respective HJ flanges **104**, **108**. HJ flanges **104**, **108** extend radially outward from rounded portions of casings **102**, **106** to create connection flanges. While named "horizontal joint" flanges, as understood in the art, the HJ flanges **104**, **108** may diverge from horizontal. Each casing **102**, **106** has an inner radius (IR) (FIG. **4**) used for operations according to embodiments of the disclosure. Inner radius (IR) may vary depending on the prediction offset value being calculated. For example, inner radius (IR) may be from rotor axis A to an inner surface of each casing **102**, **106**, from rotor axis A to an outer surface of component **120**, or from rotor axis to some part of a relevant component support position **124**.

Typically, upper casing **106** is removed during maintenance to expose turbine rotor **14** and internal components of ST system **10**. Upper casing **106** can be removed by removing any insulation and external piping (not shown), removing fasteners to lower casing **102**, and lifting it away with a crane, e.g., a heavy lift crane. Components within lower casing **102** can then be serviced. In many instances, the components may also be removed, serviced and replaced, requiring alignment thereof relative to casings **102**, **106** prior to re-use. Components that may require alignment upon replacement of upper casing **106** may include, for example, a diaphragm portion **112** (FIG. **1**), an inner casing portion **114** (FIG. **1**) and one or more stationary nozzle portions **116** (FIG. **1**). It is understood that the prior list of components is not comprehensive and a wide variety of components may require alignment.

FIG. **3** shows a top down view in a top-off position of an illustrative component **120** in the form of a diaphragm **122**. FIG. **3** shows an occupied diaphragm support position **1240** having a diaphragm **122** therein; and a component (diaphragm) support position **124**E emptied of a respective diaphragm. FIG. **4** shows a partial cross-sectional view of an illustrative diaphragm **122** (shown transparent) in a component support position **124** in one side of lower casing **102**. As understood, any number of diaphragms **122** are axially spaced within casings **102**, **106** and extend within an inner radius of each casing **102**, **106** to interact with turbine blades **20** (FIG. **1**). Diaphragms **122** of lower casing **102** and upper casing **106** (not shown) mate at their respective circumferential ends **132** (FIG. **4**) to create a working fluid path with turbine blades **20** (FIG. **1**). As illustrated, each diaphragm **122** has an extension **126** at circumferential ends **132** (FIG. **4**) thereof that is supported by component support position **124**. In the example shown, component support position **124** may include a shim **128** fastened to a ledge **130** (FIG. **4** only). More particularly, component support position **124** may include ledge **130** (FIG. **4** only) on an inner radius of lower casing **102**, and shim **128** may be positioned thereon to support extension **126** of diaphragm **122**. Shim **128** and/or ledge **130** can be adjusted to align diaphragm **122** relative to turbine casing **100**, e.g., after service of ST system **10** (FIG. **1**). For example, shim **128** can be adjusted by increasing or decreasing its height relative to ledge **130** to adjust a vertical height of component **120**, i.e., to raise or lower diaphragm **122**. In addition or alternatively, shim **128** can be adjusted to change an angle (α) of an upper surface **136** thereof. In addition or alternatively, edge **130** can be adjusted similarly to shim **128**. While component **120** has been illustrated and described herein as a diaphragm **122**, it is understood that the teachings of the disclosure are applicable to a wide variety of alternative components **120** within turbine casing **100**. For example, as noted, component **120** may include at least one of a diaphragm portion **112** (FIG. **1**) (of diaphragm **122**), an inner casing portion **114** (FIG. **1**) and one or more stationary nozzle portions **116** (FIG. **1**). Further, while component support position **124** has been described as a ledge and shim arrangement, it is understood that a shim **128** may not be necessary, and ledge **130** could be adjusted alone. Further, it is emphasized that component support position **124** may take a variety of alternative forms other than a ledge and shim arrangement, and may include any form of support for a component **120**. Component support position **124** may also be located at a different location than indicated in FIGS. **3-4**, depending on the component. The component support position can also be directly on HJ flange **104**, **108**. The adjustment may be made by means of an adjusting screw or bolt.

In accordance with embodiments of the disclosure, parts of turbine casing **100** can be provided with a number of selected reference points (RP) that can be used to calculate a prediction offset value that can be employed to adjust a component support position **124** to improve alignment of component **120** positioned at component support position **124** relative to rotor axis A upon replacing upper casing **106** to the top-on position.

As shown in FIGS. **2** and **4**, turbine casing **100** may include a plurality of first optical targets **140**. Each first optical target **140** is positioned at one of a plurality of axial locations relative to a radially facing outer surface **142** of lower HJ flange **104** of lower casing **102**. In certain embodiments, first optical targets **140** are coupled to radially facing outer surface **142** of lower HJ flange **104**; however, other locations on an outer surface of lower casing **102** may be possible. Each first optical target **140** may include any now known or later developed optical target capable of detection using an appropriate measurement system. In one non-limited example, first optical target(s) **140** may include a spherically mounted retroreflector (SMR) adapter coupled to radially facing outer surface **142** of lower HJ flange **104** of lower casing **102**. First optical target(s) **140** may be coupled to radially facing outer surface **142** in any now known or later developed manner, e.g., welding, fasteners, etc. In one example, a measurement system **144** for measuring a location of optical target(s) **140** may include, for example, a laser measurement system such as a Vantage model laser tracker available from FARO Corp. of Lake Mary, FL, or a model AT401 laser tracker available from Leica Geosystems Inc. of Norcross, GA. Measurement system **144** may be operatively coupled to an alignment system **146**, described herein. While a laser measurement system has been listed herein as an example, it is understood that wide variety of alternative measurement systems are available that are capable of the locating a reference point in three-dimensional space. Measurement system **144** may include but is not limited to: infrared, radar, etc.

For purposes that will be described herein, turbine casing **100** may also include a second optical target **148** positioned at one or more of axial locations with first optical targets **140**. Axial locations that include both optical targets **140**, **148** are referred to hereafter as "primary axial locations," while those with only first optical target **140** are referred to hereafter as "secondary axial locations." As shown best in FIG. **4**, each second optical target **148** is vertically spaced from a respective first optical target **140**, e.g., on radial facing outer surface **142** of lower HJ flange **104**, by a distance D**1**. This vertical spacing D**1** may vary depending on, for example, the size of lower HJ flange **104**. The vertical spacing D**1** is predefined such that a spatial relationship between optical targets **140**, **148** at the selected primary axial locations is known. In one non-limited example, second optical targets **148** may also include an SMR adapter coupled to an outer surface of lower HJ flange **104** of lower casing **102**. Second optical target(s) **148** may be coupled to the outer surface in any now known or later developed manner, e.g., welding, fasteners, etc. In certain embodiments, second optical targets **148** are coupled to radially facing outer surface **142** of lower HJ flange **104**; however, other locations on an outer surface of lower casing **102** may be possible. In the example shown, three second optical targets **148** are shown, resulting in three primary axial locations, but any number may be employed. As illustrated, first optical targets **140** alone may also be positioned on lower HJ flange **104** at a number of secondary axial locations at which no second optical target **148** is present. If reference is made to simply "axial location" it refers to any axial location—primary and/or secondary axial locations, or other axial locations. The purposes of optical targets **140**, **148** and the primary and secondary axial locations will be described herein.

FIG. **4** shows a number of reference points that can be used to identify issues that can impact any necessary adjustment to component support position **124**. The locations of the reference points relative to lower HJ flange **104** and/or upper HJ flange **108** may be predefined based on the geometry at the desired axial location of lower casing **102**, and can be measured by measurement system **144** according to embodiments of the disclosure. As will be described, the locations can be used by alignment system **146** to calculate a prediction offset value for one or more component support positions **124** in the top-on position. Adjusting component support position **124** in turbine casing **100** (FIG. **2**) by the prediction offset value improves an alignment of component **120** (FIG. **3**) positioned at component support position **124** relative to rotor axis A upon replacing upper casing **106** to the top-on position. In the disclosure, a 'reference point' indicates a fixed position on the upper or lower casing, e.g., of an optical target or other selected position, while a 'location of a reference point X' indicates a changeable, three dimensional position of a reference point X, e.g., as measured by measurement system **144**. The locations will be numbered, i.e., first, second, third, etc., for differentiation purposes. Note, each reference point may have a number of locations. In any event, locations may be indicated by any now known or later developed three dimensional coordinate system, e.g., using measurement system **144** as an origin. Measurement system **144**, as noted, may include any appropriate measurement system for measuring locations of reference points on casings **102**, **106**, e.g., using lasers. Alignment system **146** may receive the locations of the reference points at measurement module **230** (FIG. **12**) where calculation module **232** (FIG. **12**) calculates the prediction offset value.

As shown in FIG. **4**, the following illustrative reference points may be defined at each selected primary axial location: a first reference point RP**1** at first optical target **140** coupled to an outer surface **142** (FIG. **2**) of lower HJ flange **104**; a second reference point RP**2** at second optical target **148** coupled to outer surface **142** (FIG. **2**) of lower HJ flange **104** and vertically spaced from first optical target **140** (FIG. **2**); a third reference point RP**3** on upper surface **150**; and a fourth reference point RP**4** on upper surface **150**. As will be described, upper casing **106** may include a number of reference points thereon including, for example, a fifth reference point RP**5** on a lower (as drawn) surface **152** of upper HJ flange **108** and a sixth reference point RP**6** on lower surface **152** of upper HJ flange **108**. In addition, secondary axial locations may also include reference points. As noted, secondary axial locations do not include second optical target **148** coupled to outer surface **142** (FIG. **2**) of lower HJ flange **104**. As shown in FIG. **22**, secondary axial locations may include seventh, eighth and ninth reference points RP**7**, RP**8** and RP**9**. As will be further described, seventh, eighth and ninth reference points RP**7**, RP**8** and RP**9** correspond in function to first, third and fourth reference points (RP**1**, RP**3**, RP**4**) at primary axial locations.

In accordance with embodiments of the disclosure, at least one of the reference points has a known spatial relationship to component support position **124** such that a change in position of the reference point, i.e., as calculated in the form of the prediction offset value, can be used to adjust component support position **124** to provide the necessary change in position to component **120** (FIGS. **3** and **15**) to ensure alignment thereof in the top-on position. In the example shown, third reference point RP**3** has a known spatial relationship with component support position **124**, e.g., ledge **130** and/or shim **128**. The spatial relationship may be in any form. That is, a direct relationship in which third reference point RP**3** may have a defined vertical and/or radial offset from component support position **124**, and/or an indirect relationship in which third reference point RP**3** and component support position **124** each having a known relationship to another point, e.g., inner edge **154** of lower casing **102**. In any event, the spatial relationship can be used to calculate changes for component support position **124**. At secondary axial locations, seventh reference point RP**7** (FIG. **22**) may provide the same function as third reference point RP**3** for primary axial locations, i.e., it has a known spatial relationship with component support position **124** at the respective secondary axial location.

As observed in FIG. **4**, spatial relationships between the reference points can be defined based on the known (expected) geometry of lower HJ flange **104** at each axial location. That is, the reference points can be used to define an expected spatial relationship for each axial location as lower HJ flange **104** and/or upper HJ flange **108** changes along axial cross-sections. For example, distance D**1** between first and second reference points RP**1**, RP**2** is defined. In addition, each axial location may have a different third reference point RP**3** and fourth reference point RP**4** and/or fifth reference point RP**5** and sixth reference point RP**6** that are selected, for example, to avoid structure at a given axial location, e.g., cooling channels as shown in FIG. **14**. Regardless, each set of third and fourth reference points RP**3**, RP**4** and each set of fifth reference points RP**5**, RP**6** may have defined spatial relationships with each other and other reference points, which can be verified through measurement in the top-off position. For example, a defined distance D**2** between third and fourth reference points RP**3** and RP**4** (and RP**5** and RP**6**) is defined and can be more precisely verified by measurement for each axial location. Further, fourth reference point RP**4** may be a defined distance D**3** from outer edge **156** of lower HJ flange **104**, and first reference point RP**1** (i.e., first optical target **140**) may be a defined distance D**4** from outer edge **156** of lower HJ flange **104**. As a result, a triangular spatial relationship **160** (see differently shaded triangle in FIG. **4**) between first reference point RP**1**, third reference point RP**3** and fourth reference point RP**4**, is known and can be verified through measurement. Fifth location L**5** of third reference point RP**3** on upper surface **150** of lower HJ flange **104**, sixth location L**6** of fourth reference point RP**4** on upper surface **150** of lower HJ flange **104**, and third location L**3** of first reference point RP**1** at first optical target **140** in the top-off position, may be measured at a selected axial location to identify (verify) triangular spatial relationship **160**. Consequently, as will be described, differences between an actual location of third reference point RP**3** as measured in the top-off position and a predicted top-on location thereof based on a translation of triangular spatial relationship **160** to the top-on position (i.e., based on a location of the first reference point RP**1** in the top-on position), can be used to calculate at least one form of the prediction offset value. Similar relationships exist for seventh, eighth, and ninth reference points RP**7**, RP**8** and RP**9** (FIG. **22**) at secondary axial locations.

As noted, FIG. **4** also shows upper casing **106** with a number of reference points thereon (internal components not shown for upper casing **106**). For example, upper casing **106** may include fifth reference point RP**5** on lower (as drawn) surface **152** of upper HJ flange **108** and sixth reference point RP**6** on lower surface **152** of upper HJ flange **108**. In a top-on position, fifth reference point RP**5** is aligned with third reference point RP**3**, and sixth reference point RP**6** is aligned with fourth reference point RP**4**. Therefore, fifth and sixth reference points RP**5** and RP**6** may be distance D**2** apart. Fifth and sixth reference points RP**5** and RP**6** locations may also be known relative to edges of upper HJ flange **108**.

Reference points can be defined relative to casings **102**, **106** by optical targets **140**, **148**, or by any other mechanism by which measurement system **144** can measure their location, e.g., marks or objects on a surface detectable by measurement system **144**, temporary measurement targets placed at the reference point (e.g., optical target, reflective tape, scribe marks, stamped marks, etc.), etc.

B. Possible Casing Issues

FIGS. **5**-**11** show schematic cross-sectional views of possible HJ flange **104**, **108** scenarios that may occur during a maintenance operation in which upper casing **106** is removed from lower casing **102**, i.e., to a top-off position. The scenarios illustrated can occur at any axial location, and at one or both sides of lower casing **102**. Each scenario may impact alignment of components **120** (FIG. **3**) within turbine casing **100** differently, and can be addressed according to the methodology described herein. For purposes of description, FIGS. **5**-**11** illustrate HJ flanges **104**, **108** from a perspective in which turbine rotor axis A is to the left of the side shown. As will be described, rotor axis A acts as a coordinate system origin for the methodology described. For brevity, rotor axis A is only shown in FIG. **5**; however, a reference line RL at which flanges **104**, **108** could potentially meet has been provided. Most of the parts that curve away for casings **102**, **106** have been omitted for clarity. It is appreciated that the diametrically opposing side of each casing **102**, **106** from that shown may have similar, symmetrical positioning.

As understood the in the art, when HJ flanges **104**, **108** are separated, lower casing **102** and lower HJ flange **104** may spring upwardly or bow, and upper casing **106** and upper HJ flange **108** may drop or spring downwardly. As this occurs, lower HJ flange **104** rotates about rotor axis A, changing vertical positioning. Further, lower HJ flange **104** may tilt inwardly, tilt outwardly or simply move vertically. Similarly, upper HJ flange **108** may tilt inwardly, tilt outwardly or simply move vertically. In addition, an upper surface **150** of lower HJ flange **104**, and a lower surface **152** of upper HJ flange **108** may distort upon separation, i.e., the surfaces become non-planar. In this latter case, when casings **102**, **106** are mated together again, surfaces **150**, **152** may not meet in a surface-to-surface mating fashion, e.g., planar surface to planar surface, which may cause edges of casings **102**, **106** to not close, creating a leak. While casings **102**, **106** can be forcibly brought into planar engagement by way of fasteners that couple them together, the meeting of edges rather than surfaces, e.g., inner edges **154** or outer edges **156**, may impact the alignment of component **120** (FIG. **3**) inside the casings.

While FIGS. **5**-**11** show schematic cross-sectional views of possible HJ flange **104**, **108** scenarios that may occur, they do not necessarily show the rotation of lower casing **102** about rotor axis A. Calculation of a prediction offset value (vertical adjustment) based on the rotation, among other things, will be illustrated elsewhere in the drawings.

FIG. **5** shows an illustrative scenario **1** in which both HJ flanges **104**, **108** are parallel, i.e., surfaces **150**, **152** thereof are parallel to one another and reference line (RL). If brought together, inner edges **154** would meet nearly simultaneously with outer edges **156**, so the joint would not be open on either side. In this case, casings **102**, **106** have not tilt, they simply separated from one another vertically.

FIG. **6** shows an illustrative scenario **2** in which HJ flanges **104**, **108** are not parallel and have tilt such that, if brought together, inner edges **154** would be initially separated, and outer edges **156** would touch first, leaving the joint open on the inside (left side, as shown). In the scenario illustrated, lower HJ flange **104** tilt counterclockwise, and upper HJ flange **108** tilt clockwise.

FIG. **7** shows an illustrative scenario **3** in which both HJ flanges **104**, **108** are not parallel and have tilt such that, if brought together, outer edges **156** would be initially separated, and inner edges **154** would touch first, leaving the joint open on the outside (right side, as shown). In the scenario illustrated, lower HJ flange **104** tilt clockwise, and upper HJ flange **108** tilt counterclockwise.

FIG. **8** shows an illustrative scenario **4** in which HJ flange **104**, **108** are not parallel and lower HJ flange **104** has tilt such that, if brought together, inner edges **154** would be initially separated, and outer edges **156** would touch first, leaving the joint open on the inside (left side, as shown). In the scenario illustrated, lower HJ flange **104** tilt counterclockwise, and upper HJ flange **108** did not tilt and remains parallel, e.g., to reference line RL.

FIG. **9** shows an illustrative scenario **5** in which HJ flanges **104**, **108** are not parallel and lower HJ flange **104** has tilt such that, if brought together, inner edges **154** would be initially separated, and inner edges **154** would touch first, leaving the joint open on the outside (right side, as shown). In the setting illustrated, lower HJ flange **104** tilt clockwise, and upper HJ flange **108** did not tilt and remains parallel, e.g., to reference line RL.

FIG. **10** shows an illustrative scenario **6** in which both HJ flanges **104**, **108** are parallel and both have tilt. Here, however, if brought together, inner edges **154** would meet nearly simultaneously with outer edges **156**, so the joint would not be open on either side. In the scenario illustrated, lower HJ flange **104** tilt clockwise, and upper HJ flange **108** tilt clockwise.

FIG. **11** shows an illustrative scenario **7** in which both HJ flanges **104**, **108** are parallel and both have tilt. Here, similar to FIG. **10**, if brought together, inner edges **154** would meet nearly simultaneously with outer edges **156**, so the joint would not be open on either side. In the scenario illustrated, lower HJ flange **104** tilt counterclockwise, and upper HJ flange **108** tilt counterclockwise.

Another issue that can occur in any of the previous scenarios is that surfaces **150**, **152** may not be planar after casing **102**, **106** separation. In this setting, inner edges **154** may not be in the same plane as outer edge **156**, or other point(s) therebetween may make the surfaces non-planar.

C. Alignment System

Certain aspects of the disclosure may be embodied as an alignment system **146**, method or computer program product. Accordingly, the present disclosure may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, microcode, etc.) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a "circuit," "module" or "system." Furthermore, the present disclosure may take the form of a computer program product embodied in any tangible medium of expression having computer-usable program code embodied in the medium.

Any combination of one or more computer usable or computer readable medium(s) may be utilized. The computer-usable or computer-readable medium may be, for example but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, device, or propagation medium. More specific examples (a non-exhaustive list) of the computer-readable medium would include the following: an electrical connection having one or more wires, a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), an optical fiber, a portable compact disc read-only memory (CD-ROM), an optical storage device, a transmission media such as those supporting the Internet or an intranet, or a magnetic storage device. Note that the computer-usable or computer-readable medium could even be paper or another suitable medium upon which the program is printed, as the program can be electronically captured, via, for instance, optical scanning of the paper or other medium, then compiled, interpreted, or otherwise processed in a suitable manner, if necessary, and then stored in a computer memory. In the context of this document, a computer-usable or computer-readable medium may be any medium that can contain, store, communicate, propagate, or transport the program for use by or in connection with the instruction execution system, apparatus, or device. The computer-usable medium may include a propagated data signal with the computer-usable program code embodied therewith, either in baseband or as part of a carrier wave. The computer usable program code may be transmitted using any appropriate medium, including but not limited to wireless, wireline, optical fiber cable, RF, etc.

Computer program code for carrying out operations of the present disclosure may be written in any combination of one or more programming languages, including an object oriented programming language such as Java, Smalltalk, C++ or the like and conventional procedural programming languages, such as the "C" programming language or similar programming languages. The program code may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider).

The present disclosure is described below with reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems) and computer program products according to embodiments of the disclosure. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer program instructions. These computer program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

These computer program instructions may also be stored in a computer-readable medium that can direct a computer or other programmable data processing apparatus to function in a particular manner, such that the instructions stored in the computer-readable medium produce an article of manufacture including instruction means which implement the function/act specified in the flowchart and/or block diagram block or blocks.

The computer program instructions may also be loaded onto a computer or other programmable data processing apparatus to cause a series of operational steps to be performed on the computer or other programmable apparatus to produce a computer implemented process such that the instructions which execute on the computer or other programmable apparatus provide processes for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

FIG. **12** shows an illustrative environment **200** for alignment system **146**. To this extent, environment **200** includes a computer infrastructure **202** that can perform the various process steps described herein for alignment system **146**. In particular, computer infrastructure **202** is shown including a computing device **204** that comprises alignment system **146**, which enables computing device **204** to receive measurements and calculate prediction offset value for adjustments for casings **102**, **106**, i.e., by performing the process steps of the disclosure.

Computing device **204** is shown including a memory **212**, a processor (PU) **214**, an input/output (I/O) interface **216**, and a bus **218**. Further, computing device **204** is shown in communication with an external I/O device/resource **220** and a storage system **222**. As is known in the art, in general, processor **214** executes computer program code, such as alignment system **146**, that is stored in memory **212** and/or storage system **222**. While executing computer program code, processor **214** can read and/or write data, such as alignment system **146**, to/from memory **212**, storage system **222**, and/or I/O interface **216**. Bus **218** provides a communications link between each of the components in computing device **204**. I/O device **216** can comprise any device that enables a user to interact with computing device **204** or any device that enables computing device **204** to communicate with one or more other computing devices. Input/output devices (including but not limited to keyboards, displays, pointing devices, etc.) can be coupled to the system either directly or through intervening I/O controllers.

In any event, computing device **204** can comprise any general purpose computing article of manufacture capable of executing computer program code installed by a user (e.g., a personal computer, server, handheld device, etc.). However, it is understood that computing device **204** and alignment system **146** are only representative of various possible equivalent computing devices that may perform the various process steps of the disclosure. To this extent, in other embodiments, computing device **204** can comprise any specific purpose computing article of manufacture comprising hardware and/or computer program code for performing specific functions, any computing article of manufacture that comprises a combination of specific purpose and general purpose hardware/software, or the like. In each case, the program code and hardware can be created using standard programming and engineering techniques, respectively.

Similarly, computer infrastructure **202** is only illustrative of various types of computer infrastructures for implementing the disclosure. For example, in one embodiment, computer infrastructure **202** comprises two or more computing devices (e.g., a server cluster) that communicate over any type of wired and/or wireless communications link, such as a network, a shared memory, or the like, to perform the various process steps of the disclosure. When the communications link comprises a network, the network can comprise any combination of one or more types of networks (e.g., the Internet, a wide area network, a local area network, a virtual private network, etc.). Network adapters may also be coupled to the system to enable the data processing system to become coupled to other data processing systems or remote printers or storage devices through intervening private or public networks. Modems, cable modem and Ethernet cards are just a few of the currently available types of network adapters. Regardless, communications between the computing devices may utilize any combination of various types of transmission techniques.

As previously mentioned and discussed further below, alignment system **146** enables computer infrastructure **202** to calculate prediction offset value(s) that can be used to make adjustments to improve alignment of components **120** (FIG. **4**) within casings **102**, **106** (FIG. **4**). To this extent, alignment system **146** is shown including a measurement module **230**, and a calculation module **232**. Other system components **234** may also be provided. Operation of each of these systems is discussed further below. However, it is understood that some of the various systems shown in FIG. **12** can be implemented independently, combined, and/or stored in memory for one or more separate computing devices that are included in computer infrastructure **202**. Further, it is understood that some of the systems and/or functionality may not be implemented, or additional systems and/or functionality may be included as part of environment **200**.

Alignment system **146** may be geographically located on-site, local to turbine system **10**, or it may be geographically remote from turbine system **10**, e.g., in a centralized turbine system control center.

D. Operational Methodology

Referring to the flow diagram of FIG. **13**, a method of aligning a component **120** (FIG. **3**) within turbine casing **100** (FIG. **2**) will now be described. FIG. **14** shows a perspective view of an illustrative lower casing **102** with a number of axial locations highlighted with cross-sectional planes, FIG. **15** shows an enlarged cross-sectional view of one side of HJ flanges **104**, **108** in a top-on position of the turbine casing, FIG. **16** shows an enlarged cross-sectional view of one side of HJ flanges **104**, **108** in an illustrative top-off position of the turbine casing, and FIG. **17** shows an enlarged, schematic cross-sectional view of an illustrative HJ flange **104** show potential adjustments. In FIGS. **15-17**, rotor axis A is to the left (off the page), as illustrated. As will be described, a number of processes occur with lower casing **102** and upper casing **106** attached in a top-on position, as shown in FIGS. **2** and **15**, and a number of processes occur with lower casing **102** and upper casing **106** in a de-coupled, top-off position, as shown in for example, FIGS. **3-11**, **14** and **16**.

Processes P**10**-P**22** are carried out for at least one primary axial location along rotor axis A (FIG. **1**), i.e., where first and second optical targets **140**, **148** are both present (three shown in example in FIG. **2**). As observed in FIG. **14**, lower HJ flange **104** can change over an axial length thereof. For example, at different axial locations of lower HJ flange **104** (and upper HJ flange **108**), it can have different, for example: shape, radial position relative to turbine rotor axis A, radial thickness, and/or structure therein (e.g., cooling channels (see e.g., FIG. **14**)) extending therethrough. Processing according to embodiments of the disclosure can be carried out at different axial locations to provide highly customized adjustments for component support positions **124** at each axial location. In addition, since different sides of lower and upper casings **102**, **106** can be differently situated even if evaluated at the same axial location, processes P**10**-P**34** can be carried out at one or both sides **110**L, **110**R (FIG. **14**) of turbine casing **100** (FIG. **2**) at each axial location. While one primary axial location can be used, it is typically advantageous to use a plurality of primary axial locations to obtain better improvement in overall alignment.

Referring to FIGS. **12** and **13**, processes P**10** and P**12** are performed with lower and upper casings **102**, **106** in a top-on position, as shown in FIG. **15**. That is, upper casing **106** is coupled to lower casing **102** in a top-on position. In process P**10**, as shown in FIG. **15**, measurement system **144** measures a first location L**1** of first reference point RP**1** at first optical target **140**. As noted, first optical target **140** is coupled to outer surface **142** of lower HJ flange **104**. Measurement system **144**, as noted, may include any appropriate measurement system for measuring locations of reference points on casings **102**, **106**, e.g., using lasers. As noted, locations may be indicated by any now known or later developed three dimensional coordinate system.

In process P**12**, as shown in FIG. **15**, measurement system **144** measures a second location L**2** of a second reference point RP**2** at a second optical target **148** coupled to outer surface **142** (FIG. **2**) of lower HJ flange **104** and vertically spaced from first optical target **140** (FIG. **2**). As noted, distance D**1** between first and second reference points RP**1**, RP**2** is defined, i.e., known. With processes P**10** and P**12**, alignment system **146** may receive locations L**1**, L**2** of reference points RP**1**, RP**2** at measurement module **230** for use by calculation module **232** to calculate the prediction offset value. Note, optional process P**24** occurring in a top-on position will be described further herein.

In process P**14**, and as shown in FIG. **16**, upper casing **106** is removed from lower casing **102**. This operation can be completed using any now known or later developed casing removal process including, for example, removing any insulation, piping, casing fasteners, etc., and lifting upper casing **106** off of lower casing **102**. Upper casing **106** can be set aside for separate evaluation, as will be described herein. While not necessary, other parts that are internal to turbine casing **100** (FIG. **2**) may also be removed such as but not limited to: remaining portions of upper casing **106**, turbine rotor **14** (FIG. **1**), a lower portion of diaphragm **122** (lower diaphragm), and/or lower casing **102** portions. As shown in FIG. **13**, process P**12** and P**14** (and P**24**) may repeat for each primary (or secondary) axial location desired, e.g., three primary axial locations are shown in FIGS. **2** and **14**, and over 20 secondary axial locations are shown in FIG. **2**.

Processes P**16**-P**22**, and optional steps P**26**-P**30**, are performed with lower and upper casings **102**, **106** in a top-off position, as shown in FIG. **16**. As shown in FIG. **16**, with upper casing **106** removed, lower casing **102**, and in particular, lower HJ flange **104** thereof, may shift position, e.g., spring upward, rotate about rotor axis A, tilt inwardly or outwardly, etc. FIG. **16** shows only one possible scenario which matches FIG. **6** but includes rotation; however, lower casing **102** may take any position described in FIGS. **5-11**. It is understood that the processing may be applied to any scenario.

In process P**16**, with at least upper casing **106** removed from lower casing **102** in a top-off position, measurement system **144** measures a third location L**3** of first reference point RP**1** at first optical target **140**. Further, in process P**18**, with at least upper casing **106** removed from lower casing **102** in a top-off position, measurement system **144** measures a fourth location L**4** of second reference point RP**2** at second optical target **148**. The shift in position of lower casing **102** can be observed by comparing third and fourth locations L**3**, L**4** to first and second locations L**1**, L**2** (FIG. **15**, and shown in phantom in FIG. **16**). In the FIG. **16** example, lower HJ flange **104** has moved vertically upward and tilt inwardly (counterclockwise) from the position shown in FIG. **15**. Lower HJ flange **104** may have also rotated, e.g., counterclockwise, about rotor axis A.

In process P**20**, with at least upper casing **106** removed from lower casing **102** in a top-off position, measurement system **144** measures a fifth location of third reference point RP**3** on upper surface **150** of lower HJ flange **104**. As noted, third reference point RP**3** has a known spatial relation to component support position **124** of component **120** in lower casing **102**.

In process P**22**, with at least upper casing **106** removed from lower casing **102** in a top-off position, measurement system **144** measures a sixth location of fourth reference point RP**4** on upper surface **150** of lower HJ flange **104** of lower casing **102**. As noted, fourth reference point RP**4** is spaced from third reference point RP**3** on upper surface **150** of lower HJ flange **104** by a distance D**1**. After processes P**16**-P**22**, alignment system **146** may receive locations L**3**, L**4**, L**5** and L**6** of reference points RP**1**, RP**2**, RP**3**, RP**4**, respectively, at measurement module **230** (FIG. **12**) for use by calculation module **232** (FIG. **12**) to calculate the prediction offset value. As shown in FIG. **16**, triangular spatial relationship **160** of reference points RP**1**, RP**3** and RP**4** can be measured, i.e., verifying actual spacing and angular relationships thereof, at each axial location.

With reference to FIGS. **13** and **22**, processes P**24**-P**30** are optional measurement steps for secondary axial locations. In process P**24**, in a top-on position shown partially in FIG. **22**, measurement system **144** measures a seventh location L**7** of a seventh optical target RP**7** at a first optical target **140** at secondary axial location (just RP**7** at seventh location L**7** of lower casing **102** shown in top-on position in FIG. **22**). Seventh reference point RP**7** is substantially identical in function to first reference point RP**1**, except it is for a secondary axial location. That is, first optical target **140** is located at a different axial location than first optical target **140** in FIG. **16**. In process P**26**, in a top-off position, shown in FIG. **22**, measurement system **144** measures an eighth location L**8** of seventh reference point RP**7** at first optical target **140** at the secondary axial location. In process P**28**, in a top-off position, measurement system **144** measures a ninth location L**9** of an eighth reference point RP**8** on upper surface **150** of lower HJ flange **104**. Eighth reference point RP**8** is substantially identical in function to third reference point RP**3**, except it is for a secondary axial location. Hence, eighth reference point RP**8** has a known spatial relation to the component support position **124** of component **120** (FIG. **4**) in lower casing **102** at the respective secondary axial location. In process P**28**, in a top-off position, measurement system **144** measures, a tenth location L**10** of a ninth reference point RP**9** on upper surface **150** of lower HJ flange **104**. Ninth reference point RP**9** is substantially identical in function to fourth reference point RP**4**, except it is for a secondary axial location. Hence, ninth reference point RP**9** is spaced from eighth reference point RP**8** on upper surface **150** of lower HJ flange **104**.

Top-off position measurement processes (P**16**-P**30**) may repeat for any desired number of primary and/or secondary axial locations. Measurement module **230** (FIG. **12**) may receive all of the measured locations L**1**-L**10**.

In process P**32**, calculation module **232** (FIG. **12**) may calculate the prediction offset value for component support position **124** in the top-on position based on first, second, third, fourth, fifth and sixth locations L**1**-L**6** and inner radius (IR) of lower casing **102** for at least one of the primary axial locations. In addition, calculation module **232** (FIG. **12**) may also calculate the prediction offset value for component support position **124** in the top-on position based on seventh, eighth, ninth and tenth locations L**7**-L**10** and inner radius (IR) of lower casing **102** for at least one of the secondary axial location(s). It is also noted that calculation of the prediction offset value for component support position **124** in the top-on position for a first side of the turbine casing **100** includes accounting for the prediction offset value for the component support position **124** in the top-on position for a second, opposite side of the turbine casing. That is, the calculation balances the prediction offset value for each side to ensure changes to one side do not negatively impact or disturb changes to the other side, e.g., rotational adjustments that counteract one another.

Process P**32** can take a variety of forms that can be performed individually, or together, in any combination. Consequently, the prediction offset value can take a variety of forms.

In process P**34**, the method may include a user adjusting component support position **124** in turbine casing **100** (FIG. **2**) by the prediction offset value. The adjusting changes component support position **124** position to improve an alignment of component **120** (FIG. **15**) with rotor axis A upon replacing upper casing **106** of turbine casing **100** (FIG. **2**) to the top-on position. The adjusting may include, for example, as shown in FIG. **17**, a change in a height (H) of component support position **124**, e.g., by changing shim **128** and/or ledge **130**. In any event, an alignment of component **120** (FIG. **4**) positioned at component support position **124** is improved relative to rotor axis A upon replacing upper casing **106** to the top-on position (FIG. **15**). Process P**34** can take a variety of forms that can be performed individually, or together, in any combination, e.g., depending on the prediction offset value form.

The following sections will further describe the types of prediction offset value(s) that can be calculated by calculation module **232** (FIG. **12**) in process P**32**, and the related adjustment(s) that can be performed based on the prediction offset value(s) in process P**34**.

a. Prediction Offset Value with Vertical Adjustment

In certain embodiments, prediction offset value may include a vertical adjustment. In a simplified form, as shown in FIG. **16**, vertical adjustments can be determined directly from a vertical change in first location L**1** and third location L**3** of first reference point RP**1**, i.e., between the top-on position and the top-off position.

As described previously, and as shown in detail in FIG. **17**, third reference point RP**3** and fourth reference point RP**4** on upper surface **150** of lower HJ flange **104**, and first reference point RP**1** at first optical target **140**, define triangular spatial relationship **160** (shaded triangle). More specifically, triangular spatial relationship **160** represents the location of reference points RP**1**, RP**3** and RP**4** on lower HJ flange **104** as they are expected to exist. Triangular spatial relationship **160** thus provides a baseline through which changes in lower HJ flange **104** can be detected. Triangular spatial relationship **160** can be identified, for example, based on initial designs and/or manufacturing records of lower HJ flange **104**, or based on previous manufacturing records of changes to lower HJ flange **104**. However, triangular spatial relationship **160** may also be identified (or verified) by calculation module **232** (FIG. **12**) based on the measured locations of reference points RP**1**, RP**3**, RP**4** on lower HJ flange **104** in the top-off position in process P**16**, P**20** and P**22**. As shown in FIG. **16**, calculation module **232** also determines a rotation angle (α) of lower HJ flange **104** about rotor axis A by calculating an angle between a first vector V**1** extending from rotor axis A to first location L**1** of first optical target **140** in top-on position and a second vector V**2** from rotor axis A through third location L**3** of first optical target **140** in the top-off position.

As shown in FIG. **18**, calculation module **232** can translate triangular spatial relationship **160** to the top-on position based on first reference point RP**1** at first location L**1** in the top-on position and rotation angle (α) of lower HJ flange **104** about rotor axis A. That is, it rotates the triangular spatial relationship by rotation angle (α). The translating creates a predicted top-on location LP for third reference point RP**3** in the top-on position. In other words, calculation module **232** virtually places triangular spatial relationship **160** in the top-on position, using first reference point RP**1** as the starting point. As shown in FIG. **18**, triangular spatial relationship **160** may be moved vertically and/or rotated to match the rotation angle (α) of lower HJ flange **104** in the top-on position. In this setting, predicted top-on location LP of third reference point RP**3** indicates where vertically third reference point RP**3** should be if there is no distortion in lower HJ flange **104**. Calculation module **232** calculates any vertical difference (Δz1) between (actual) fifth location L**5** of third reference point RP**3** as measured and predicted top-on location LP for third reference point RP**3** from expected triangular spatial relationship **160**. Any vertical difference (Δz1) indicates a vertical change (FIGS. **17** and **18**) in the location of third reference point RP**3** caused, for example, by distortion in lower HJ flange **104** from use. Calculation module **232** (FIG. **12**) calculates a vertical adjustment based on any vertical difference (Δz1) of lower HJ flange **104**.

Process P**34** may include adjusting component support position **124** to one of raise or lower (H) the component support position **124** based on the vertical adjustment and the known spatial relation of third reference point RP**3** to component support position **124** of component **120** in lower casing **102**. For example, if predicted top-on position LP is 1 millimeter higher than the actual, fifth location L**5** of third reference point RP**3**, then component support position **124**, e.g., ledge **130** and/or shim **128**, can be lowered in the tops off condition to accommodate the distortion in lower HJ flange **104** so that it is in the correct location when the tops is on and bolted.

In other embodiments, as also shown in FIG. **16**, vertical adjustments can also be determined from based on a tilt angle (β) of lower HJ flange **104**, i.e., between the top-on position and the top-off position. That is, tilt angle (β) of lower HJ flange **104** also indicates a vertical change of third reference point RP**3** between the top-on position and the top-off position. Here, calculation module **232** (FIG. **12**) calculates the prediction offset value by, as shown in FIG. **16**, determining a tilt angle (β) of lower HJ flange **104** by calculating an angle between a first reference line (FRL) extending through first and second locations L**1**, L**2** (shown in phantom in FIG. **16**, and solid line in FIG. **15**) of first and second optical targets **140**, **148** in top-on position (FIG. **15**), and a second reference line (SRL) extending through third and fourth locations L**3**, L**4** of first and second optical targets **140**, **148** in the top-off position (FIG. **16**). Tilt angle (β) captures any inward or outward tilting of lower HJ flange **104** that changes its radial distance from rotor axis A, and a vertical position of component support position **124**. In the scenarios of FIG. **16** and FIGS. **6**, **8** and **11**, lower HJ flange **104** tilts counterclockwise to the top-off position. In FIGS. **7**, **9** and **10** scenarios, lower HJ flange **104** tilts clockwise to the top-off position.

Here, as shown in FIG. **18**, calculation module **232** also calculates any additional vertical difference (Δz2) between (actual) fifth location L**5** of third reference point RP**3** as measured and predicted top-on location LP for third reference point RP**3** from tilt angle (β) of lower HJ flange **104**. Note, vertical difference (Δz2) is shown in an exaggerated size for purposes of clarity of illustration, e.g., Δz1 may not be smaller than Δz2. Tilt angle (β) of lower HJ flange **104** may be translated to, for example, reference point RP**4** and a vertical difference at third reference point RP**3** evaluated to identify a change in position of third reference point RP**3** caused by tilting of lower HJ flange **104**. Any vertical difference (Δz2) indicates an additional vertical change (FIG. **18**) in the location of third reference point RP**3** caused, for example, by distortion in lower HJ flange **104** from use. Calculation module **232** (FIG. **12**) calculates a vertical adjustment based on any vertical difference (Δz1) and tilt angle (β), i.e., any vertical difference (Δz2), of lower HJ flange **104**.

Process P**34**, as noted previously, may include adjusting component support position **124** to one of raise or lower (H) component support position **124** based on the vertical adjustment and the known spatial relation of third reference point RP**3** to component support position **124** of component **120** in lower casing **102**. For example, if predicted top-on position LP is a determined to be an additional 0.2 millimeters off due to tilting (i.e., collectively 1.2 millimeter higher than the actual, fifth location L**5** of third reference point RP**3**), then component support position **124**, e.g., ledge **130** and/or shim **128**, can be lowered in the tops off condition to accommodate the distortion in lower HJ flange **104** so that it is in the correct location when the tops is on and bolted.

b. Prediction Offset Value with Horizontal Adjustment

Referring to FIG. **19**, calculation module **232** calculate a first horizontal difference (Δy1) between first location L**1** of first optical target **140** in the top-on position (dashed lines) and third location L**3** of first optical target **140** in top-off position (solid lines) at a first side of lower casing **102**, and a second horizontal difference (Δy2) between first location L**1** of first optical target **140** in top-on position (dashed lines) and third location L**3** of first optical target **140** in top-off position (sold lines) at a second side of lower casing **102**. Calculation module **232** sums first horizontal difference (Δy1) and second horizontal difference (Δy2) to attain a horizontal adjustment. For example, if first horizontal difference (Δy1) is 8 units, and second horizontal difference (Δy2) is −5 units, the sum and horizontal adjustment would be 3 units.

In process P**34**, the adjusting would include adjusting component support position **124** based on the horizontal adjustment and the known spatial relation of third reference point RP**3** (FIGS. **16-18**) to component support position **124** (FIGS. **16-18**) of component **120** in lower casing **102**.

c. Prediction Offset Value with HJ Flange Surface Distortion Adjustment

Referring to FIGS. **13**, **20** and **21**, in certain embodiments, the prediction offset value may include a HJ flange **104**, **108** surface distortion adjustment to component support position **124**. FIG. **20** shows a schematic cross-sectional view of lower HJ flange **104** and upper HJ flange **108** in a top-off position with axis on the right. It is noted that while upper casing **106** is shown elevated above lower casing **102**, it may actually be laying in any orientation off of lower casing, e.g., in a support remote from lower casing **102**, flipped over on a floor, etc. As illustrated, with upper casing **106** in position to be mounted to lower casing **102** (virtually, with perhaps HJ flange surfaces beginning to touch), a gap G may exist, in the example shown, between third reference point RP**3** and fifth reference point RP**5**. Gap G represents an opening that would remain when lower casing **102** and upper casing **106** are moved to the top-on position caused by HJ flange surface distortion and in existence prior to closing the gap as upper casing **106** is fastened to lower casing **102**. As illustrated in the example of FIG. **21**, if lower casing **102** and upper casing **106** are moved to the top-on position, inner edges **154** would meet before outer edges **156** of HJ flanges **104**, **108**, creating a gap G at an outer location near third reference point RP**3** and fifth reference point RP**5**. Note, gap G is shown in an exaggerated size in the drawings for purposes of clarity of illustration. Gap G disappears as casings **102**, **106** are fastened together. It can be observed in FIG. **20** that gap G is at least partially correlated to tilt angle (β), such that a prediction offset value to address gap G can be based, in part, on tilt angle (β). In one non-limiting example, a prediction offset value to address gap G can be based on half of tilt angle (β), assuming half of tilt angle (β) is absorbed by each HJ flange **104**, **108** during reconnection of casings **102**, **106**. In process P**32**, calculation module **232** can calculate the prediction offset value for component support position **124** in the top-on position based on at least the first, second, third, fourth, fifth and sixth locations L**1**-L**6** of lower casing **102** and any gap G. In one example, calculation module **232** can calculate the prediction offset value to include a HJ flange surface distortion adjustment at third reference point RP**3** to accommodate half of tilt angle (β) to address gap G. It is appreciated that gap G could also be between fourth and sixth reference points RP**4**, RP**6** if HJ flanges **104**, **108** tilt in an opposite direction. It is also appreciated that no gap G may exist where HJ flanges **104**, **108** remain parallel to one another.

In process P**34**, component support position **124** (see e.g., FIG. **18**) may be adjusted in turbine casing **100** (FIG. **2**) by the prediction offset value including the HJ flange surface distortion adjustment.

In an optional embodiment, in order to confirm the presence and/or extent of gap G, in certain embodiments, as shown in FIG. **20**, calculation module **232** can also calculate any gap G at an inner location near third reference point RP**3** and fifth reference point RP**5**, or an outer location near fourth reference point RP**4** and sixth reference point RP**6** based on an angular relationship between a first reference line RL**1** and a second reference line RL**2** and the inner radius IR of lower casing **102**. Again, gap G represents an opening that would remain when lower casing **102** and upper casing **106** are moved to the top-on position caused by HJ flange surface distortion and in existence prior to closing the gap as upper casing **106** is fastened to lower casing **102**. As illustrated in the example of FIG. **21**, if lower casing **102** and upper casing **106** are moved to the top-on position, inner edges **154** would meet before outer edges **156** of HJ flanges, creating a gap at an outer location near third reference point RP**3** and fifth reference point RP**5**.

As shown in FIG. **20**, in process P**32**, calculation module **232** identifies a first reference line RL**1** through third reference point RP**3** and fourth reference point RP**4** on lower HJ flange **104** in a top-off position. Further, in process P**32**, calculation module **232** identifies a second reference line RL**2** through a fifth reference point and a sixth reference point of a lower (as shown) surface **152** of upper HJ flange **108**. As illustrated, rotor axis A is known for lower casing **102**, and a rotor axis A' is (virtually) known for upper casing **106**, e.g., the latter based on its shape, inner radius and perhaps other dimensions. As shown in FIG. **21**, calculation module **232** establishes an angular relationship between first reference line RL**1** and second reference line RL**2** by superimposing rotor axis A' of upper HJ flange **108** in the top-off position with rotor axis A of lower HJ flange **104** in the top-off position. Calculation module **232** can then calculate (confirm) any gap G at an inner location near third reference point RP**3** and fifth reference point RP**5**, or an outer location near fourth reference point RP**4** and sixth reference point RP**6** based on the angular relationship between first reference line RL**1** and second reference line RL**2** and the inner radius IR of lower casing **102**. Again, gap G represents an opening that would remain when lower casing **102** and upper casing **106** are moved to the top-on position caused by HJ flange surface distortion and in existence prior to closing the gap as upper casing **106** is fastened to lower casing **102**. As illustrated in the example of FIG. **21**, if lower casing **102** and upper casing **106** are moved to the top-on position, inner edges **154** would meet before outer edges **156** of HJ flanges, creating a gap at an outer location near third reference point RP**3** and fifth reference point RP**5**. Gap G can be calculated (confirmed) by, for example, differencing a length of lines IL and line EL, which are both parallel to vertical axis z. IL extends between inner edges **154**, and EL extends between outer edges **156**. The location of inner and outer edges **154**, **156** can be (virtually) calculated based on the other reference points locations and inner radius IR. It is recognized, based on the scenarios in FIGS. **5**-**11**, a gap may also exist at the inner location. Calculation module **232** calculates the prediction offset value for component support position **124** in the top-on position based on at least the first, second, third, fourth, fifth and sixth locations L**1**-L**6** of lower casing **102** and any gap.

In process P**34**, component support position **124** (see e.g., FIG. **18**) may be adjusted in turbine casing **100** (FIG. **2**) by the prediction offset value including the HJ flange surface distortion adjustment.

d. Prediction Offset Value for Secondary Axial Locations

As noted previously, any number of secondary axial locations (FIG. **2**) may be provided along rotor axis A that are different than each primary axial location. As shown in FIGS. **2**, **14** and **22**, each secondary axial location includes first optical target **140** but no second optical target **148**, i.e., they have only first optical target **140**. Embodiments of the disclosure for at least one secondary axial location may occur at one or both sides of turbine casing **100**. In process P**24**-P**28**, measurement system **144** measures seventh, eighth, ninth and tenth locations L**7**-L**10**, as shown in FIGS. **13** and **22**, at a secondary axial location. Measurement module **230** (FIG. **12**) may receive locations L**7**-L**10**, and in process P**32**, calculation module **232** (FIG. **12**) may calculate the prediction offset value for component support position **124** in the top-on position based on seventh, eighth, ninth and tenth locations L**7**-L**10** and inner radius IR of lower casing **102** for at least one of secondary axial location. Any of the aforementioned prediction offset values for primary axial locations can be calculated for each secondary axial location. Where tilt angle (β) is required for the calculation, the value is unknown for each secondary axial location because no second reference point RP**2** and second optical target **148** is provided at those axial locations. In this case, the calculation may use the tilt angle (β) value of the nearest primary axial location.

In process P**34**, component support position **124** in turbine casing **100** (FIG. **2**) at secondary axial location(s) may be adjusted by the prediction offset value therefor in a similar fashion as that described relative to the primary axial locations. The alignment of component **120** (FIG. **15**) positioned at component support position **124** for secondary axial location(s) is improved relative to rotor axis A upon replacing upper casing **106** to the top-on position.

Processing may be completed by replacing any parts removed from lower casing **102** and/or upper casing **106**, and replacing upper casing **106** on lower casing **102**, and fastening it back in place per any now known or later developed technique.

E. Conclusion

Embodiments of the disclosure provide a method, system and turbine casing for aligning components that does not require numerous removing steps of the upper casing, thus making the process simpler, safer and less time consuming. The method also provides accurate results without direct measurement of component support positions. The method is also highly flexible and can handle unsymmetrical turbine casings. Technical effect is an alignment system capable of providing adjustments for one or more casings of a turbine casing to align components to be supported therein.

The flowchart and block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of systems, methods and computer program products according to various embodiments of the present disclosure. In this regard, each block in the flowchart or block diagrams may represent a module, segment, or portion of code, which comprises one or more executable instructions for implementing the specified logical function (s). It should also be noted that, in some alternative implementations, the functions noted in the block may occur out of the order noted in the figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. It will also be noted that each block of the block diagrams and/or flowchart illustration, and combinations of blocks in the block diagrams and/or flowchart illustration, can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and computer instructions.

As discussed herein, various systems and components are described as "receiving" data (e.g., locations, etc.). It is understood that the corresponding data can be obtained using any solution. For example, the corresponding system/component can include measurement system **144** or another system capable of generating and/or being used to generate the data, retrieve the data from one or more data stores (e.g., a database), receive the data from another system/component, and/or the like. When the data is not generated by the particular system/component, it is understood that another system/component can be implemented apart from the system/component shown, which generates the data and provides it to the system/component and/or stores the data for access by the system/component.

The foregoing drawings show some of the processing associated according to several embodiments of this disclosure. In this regard, each drawing or block within a flow diagram of the drawings represents a process associated with embodiments of the method described. It should also be noted that in some alternative implementations, the acts noted in the drawings or blocks may occur out of the order noted in the figure or, for example, may in fact be executed substantially concurrently or in the reverse order, depending upon the act involved. Also, one of ordinary skill in the art will recognize that additional blocks that describe the processing may be added.

Approximating language, as used herein throughout the specification and claims, may be applied to modify any quantitative representation that could permissibly vary without resulting in a change in the basic function to which it is related. Accordingly, a value modified by a term or terms, such as "about," "approximately" and "substantially," are not to be limited to the precise value specified. In at least some instances, the approximating language may correspond to the precision of an instrument for measuring the value. Here and throughout the specification and claims, range limitations may be combined and/or interchanged, such ranges are identified and include all the sub-ranges contained therein unless context or language indicates otherwise. "Approximately" as applied to a particular value of a range applies to both values, and unless otherwise dependent on the precision of the instrument measuring the value, may indicate +/−10% of the stated value(s).

The corresponding structures, materials, acts, and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or act for performing the function in combination with other claimed elements as specifically claimed. The description of the present disclosure has been presented for purposes of illustration and description, but is not intended to be exhaustive or limited to the disclosure in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the disclosure. The embodiment was chosen and described in order to best explain the principles of the disclosure and the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

What is claimed is:

1. A method of aligning a component within a turbine casing having two sides that are opposed, the turbine casing including an upper casing and a lower casing configured to collectively surround a rotor, the rotor having a rotor axis, the method comprising:

for at least one primary axial location along the rotor axis and at one or both sides of the turbine casing at each primary axial location:

with the upper casing coupled to the lower casing in a top-on position:

measuring a first location of a first reference point on the lower casing; and

measuring a second location of a second reference point on the lower casing that is spaced apart from the first reference point;

with the upper casing removed from the lower casing in a top-off position:

measuring a third location of the first reference point;

measuring a fourth location of the second reference point;

measuring a fifth location of a third reference point on the lower casing, wherein the third reference point is hidden when the upper casing is in the top-on position, the third reference point having a known spatial relation to a component support position of a respective component at the respective primary axial location; and

calculating a prediction offset value for the component support position in the top-on position based on at least the first, second, third, fourth, and fifth locations and an inner radius of the lower casing; and

adjusting the component support position in the turbine casing by the prediction offset value, wherein an alignment of the component positioned at the component support position is improved relative to the rotor axis upon replacing the upper casing to the top-on position.

2. The method of claim **1**, wherein the first reference point and the second reference point are on an outer surface of the lower casing.

3. The method of claim **1**, wherein the third reference point is on an upper surface of a horizontal joint flange of the lower casing.

4. The method of claim **1**, further comprising measuring a sixth location of a fourth reference point on the lower casing in the top-off position, wherein the fourth reference point is hidden when the upper casing is in the top-on position, and wherein the calculating the prediction offset value is also based on the sixth location.

5. The method of claim **1**, further comprising mounting a respective optical target at each reference point.

6. The method of claim **1**, wherein the at least one primary axial location includes a plurality of primary axial locations, and wherein the one or both sides of the turbine casing includes both sides of the turbine casing, and the calculating the prediction offset value for the component support position in the top-on position for a first side of the turbine casing includes accounting for the prediction offset value for the component support position in the top-on position for a second, opposite side of the turbine casing.

7. The method of claim **1**, wherein the calculating the prediction offset value includes:

identifying a triangular spatial relationship between the fifth location of the third reference point on the upper surface of the HJ flange of the lower casing, and the third location of the first reference point at the first optical target;

determining a rotation angle of the HJ flange of the lower casing about the rotor axis by calculating an angle between a first vector extending from the rotor axis to the first location of the first optical target in the top-on position and a second vector from the rotor axis through the third location of the first optical target in the top-off position;

translating the triangular spatial relationship to the top-on position based on the first reference point at the first location in the top-on position and the rotation angle of the HJ flange of the lower casing about the rotor axis, the translating creating a predicted top-on location for the third reference point in the top-on position;

calculating a vertical difference between the fifth location of the third reference point as measured and the predicted top-on location for the third reference point; and

calculating a vertical adjustment based on a vertical difference of the HJ flange of the lower casing,

wherein the adjusting includes adjusting the component support position to one of raise or lower the component support position based on the vertical adjustment and the known spatial relation of the third reference point to the component support position of the component in the lower casing.

8. The method of claim **7**, wherein the calculating the prediction offset value further includes:

determining a tilt angle of the HJ flange of the lower casing by calculating an angle between a first reference line extending through the first and second locations of the first and second reference points in the top-on position and a second reference line extending through the third and fourth locations of the first and second reference points in the top-off position;

calculating a vertical difference between the fifth location of the third reference point as measured and the predicted top-on location for the third reference point; and

calculating the vertical adjustment based on a vertical difference and the tilt angle of the HJ flange of the lower casing.

9. The method of claim **7**, wherein the calculating the prediction offset value includes:

calculating a first horizontal difference between the first location of the first reference point in the top-on position and the third location of the first reference point in the top-off position at a first side of the lower casing;

calculating a second horizontal difference between the first location of the first reference point in the top-on position and the third location of the first reference point in the top-off position at a second side of the lower casing; and

summing the first horizontal difference and the second horizontal difference to attain a horizontal adjustment, and

wherein the adjusting includes adjusting the component support position based on the horizontal adjustment and the known spatial relation of the third reference point to the component support position of the component in the lower casing.

10. The method of claim **7**, wherein the calculating the prediction offset value further includes:

with the upper casing in position to be mounted to the lower casing, calculating a gap at an inner location near the third reference point and a fifth reference point on the upper casing, or at an outer location near the fourth reference point and a sixth reference point on the upper casing, based on the tilt angle; and

calculating the prediction offset value for the component support position in the top-on position based on at least the first, second, third, fourth, fifth and sixth locations of the lower casing and the gap.

11. The method of claim **1**, wherein the calculating the prediction offset value includes:

calculating a first horizontal difference between the first location of the first reference point in the top-on position and the third location of the first reference point in the top-off position at a first side of the lower casing;

calculating a second horizontal difference between the first location of the first reference point in the top-on position and the third location of the first reference point in the top-off position at a second side of the lower casing; and

summing the first horizontal difference and the second horizontal difference to attain a horizontal adjustment, and

wherein the adjusting includes adjusting the component support position based on the horizontal adjustment and the known spatial relation of the third reference point to the component support position of the component in the lower casing.

12. The method of claim **1**, wherein the calculating the prediction offset value further includes:

with at least the upper casing removed from the lower casing in the top-off position:

identifying a first reference line through the third reference point and a fourth reference point on the HJ flange of the lower casing;

identifying a second reference line through a fifth reference point and a sixth reference point on a lower surface of the HJ flange of the upper casing, the fifth reference point aligned with the third reference point in the top-on position and the sixth reference point aligned with the fourth reference point in the top-on position;

establishing an angular relationship between the first reference line and the second reference line by superimposing the rotor axis of the HJ flange of the upper casing in the top-off position with the rotor axis of the HJ flange of the lower casing in the top-off position;

calculating a gap at an inner location near the third reference point and the fifth reference point, or at an outer location near the fourth reference point and the sixth reference point based on the angular relationship between the first reference line and the second reference line and the inner radius of the lower casing;

calculating the prediction offset value for the component support position in the top-on position based on at least the first, second, third, fourth, fifth and sixth locations of the lower casing and the gap; and

adjusting the component support position in the turbine casing by the prediction offset value, wherein an alignment of the component positioned at the component support position is improved relative to the rotor axis upon replacing the upper casing to the top-on position.

13. A system for aligning a component within a turbine casing having two sides that are opposed, the turbine casing including an upper casing and a lower casing configured to collectively surround a rotor, the rotor having a rotor axis, the system comprising:

at least one primary axial location along the rotor axis, each primary axial location including a respective first reference point on the lower casing;

a measurement module configured to, for each primary axial location and at one or both sides of the turbine casing at each primary axial location:
  with the upper casing coupled to the lower casing in a top-on position, receive a measurement of:
    a first location of the first reference point; and
    a second location of a second reference point on the lower casing that is spaced apart from the first reference point;
  with at least the upper casing removed from the lower casing in a top-off position, receive a measurement of:
    a third location of the first reference point;
    a fourth location of the second reference point; and
    a fifth location of a third reference point on the lower casing, wherein the third reference point is hidden when the upper casing is in the top-on position, the third reference point having a known spatial relation to a component support position of a respective component at the respective primary axial location; and
a calculation module configured to:
  calculate a prediction offset value for the component support position in the top-on position based on at least the first, second, third, fourth, and fifth locations and an inner radius of the lower casing; and
    indicate an adjustment for the component support position in the turbine casing at the at least one primary axial location based on the prediction offset value.

14. The system of claim **13**, wherein the measurement module is further configured to, for each primary axial location, receive a measurement of a sixth location of a fourth reference point on the lower casing, and wherein the calculation module is further configured to calculate the prediction offset value also based on the sixth location.

15. The system of claim **13**, wherein the calculation module is further configured to:
identify a triangular spatial relationship between the fifth location of the third reference point on the upper surface of the HJ flange of the lower casing, and the third location of the first reference point at the first optical target;
determine a rotation angle of the HJ flange of the lower casing about the rotor axis by calculating an angle between a first vector extending from the rotor axis to the first location of the first optical target in the top-on position and a second vector from the rotor axis through the third location of the first optical target in the top-off position;
translate the triangular spatial relationship to the top-on position based on the first reference point at the first location in the top-on position and the rotation angle of the HJ flange of the lower casing about the rotor axis, the translating creating a predicted top-on location for the third reference point in the top-on position;
calculate a vertical difference between the fifth location of the third reference point as measured and the predicted top-on location for the third reference point; and
calculate a vertical adjustment based on a vertical difference of the HJ flange of the lower casing,
wherein the indicated adjustment includes an adjustment of the component support position to one of raise or lower the component support position based on the vertical adjustment and the known spatial relation of the third reference point to the component support position of the component in the lower casing.

16. The system of claim **15**, wherein the calculation module is further configured to:
determine a tilt angle of the HJ flange of the lower casing by calculating an angle between a first reference line extending through the first and second locations of the first and second reference points in the top-on position and a second reference line extending through the third and fourth locations of the first and second reference points in the top-off position;
calculate a vertical difference between the fifth location of the third reference point as measured and the predicted top-on location for the third reference point; and
calculate the vertical adjustment based on a vertical difference and the tilt angle of the HJ flange of the lower casing.

17. The system of claim **15**, wherein the calculation module is further configured to:
calculate a first horizontal difference between the first location of the first reference point in the top-on position and the third location of the first reference point in the top-off position at a first side of the lower casing;
calculate a second horizontal difference between the first location of the first reference point in the top-on position and the third location of the first reference point in the top-off position at a second side of the lower casing; and
sum the first horizontal difference and the second horizontal difference to attain a horizontal adjustment, and
wherein the indicated adjustment includes an adjustment of the component support position based on the horizontal adjustment and the known spatial relation of the third reference point to the component support position of the component in the lower casing.

18. The system of claim **15**, wherein the calculation module is further configured to:
with the upper casing in position to be mounted to the lower casing, calculate a gap at an inner location near the third reference point and a fifth reference point on the upper casing, or an outer location near the fourth reference point and a sixth reference point on the upper casing, based on the tilt angle; and
calculate the prediction offset value for the component support position in the top-on position based on at least the first, second, third, fourth, fifth and sixth locations of the lower casing and the gap.

19. The system of claim **13**, wherein the calculation module is further configured to:
calculate a first horizontal difference between the first location of the first reference point in the top-on position and the third location of the first reference point in the top-off position at a first side of the lower casing;
calculate a second horizontal difference between the first location of the first reference point in the top-on position and the third location of the first reference point in the top-off position at a second side of the lower casing; and
sum the first horizontal difference and the second horizontal difference to attain a horizontal adjustment, and
wherein the indicated adjustment includes an adjustment of the component support position based on the horizontal adjustment and the known spatial relation of the third reference point to the component support position of the component in the lower casing.

20. The system of claim **13**, wherein the calculation module is further configured to:

with at least the upper casing removed from the lower casing in the top-off position:

identify a first reference line through the third reference point and a fourth reference point on the HJ flange of the lower casing;

identify a second reference line through a fifth reference point and a sixth reference point on a lower surface of the HJ flange of the upper casing, the fifth reference point aligned with the third reference point in the top-on position and the sixth reference point aligned with the fourth reference point in the top-on position;

establish an angular relationship between the first reference line and the second reference line by superimposing the rotor axis of the HJ flange of the upper casing in the top-off position with the rotor axis of the HJ flange of the lower casing in the top-off position;

calculate a gap at an inner location near the third reference point and the fifth reference point, or an outer location near the fourth reference point and the sixth reference point based on the angular relationship between the first reference line and the second reference line and the inner radius of the lower casing; and

calculate the prediction offset value for the component support position in the top-on position based on at least the first, second, third, fourth, fifth and sixth locations of the lower casing and the gap,

wherein the indicated adjustment includes an adjustment of the component support position in the turbine casing by the prediction offset value, and wherein an alignment of the component positioned at the component support position is improved relative to the rotor axis upon replacing the upper casing to the top-on position.

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